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PROCEEDINGS OF THE SOCIETY OF ARTS

FORTY-THIRD YEAR, 1904–1905

BOSTON, May 11, 1905.

THE 43d annual meeting (the 611th regular meeting) of the SOCIETY OF ARTS was held on this day at eight P.M., Room 22, Walker Building, Mr. G. W. Blodgett, Chairman of the Executive Committee, presiding. About fifty persons were present.

The minutes of the previous meeting were read and approved. The Secretary then read the report of the Executive Committee for the year.

The Secretary read the report of the Nominating Committee. The following were chosen as members of the Executive Committee for the ensuing year: Mr. G. W. Blodgett, Chairman, Colonel Edmund H. Hewins, Mr. James P. Munroe, Mr. A. Lawrence Rotch, Mr. Charles T. Main. S. C. Prescott was reëlected Secretary for the ensuing year.

At the end of the business meeting Mr. Blodgett introduced Mr. James F. Jackson, of the Massachusetts Railroad Commission, who spoke on the work of the commission, and described in a very interesting manner the different kinds of questions which have to be decided by the commission.

After some discussion a vote of thanks was extended to the speaker, and the Society adjourned.

SAMUEL C. PRESCOTT, *Secretary.*

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE

During the past year the SOCIETY OF ARTS has held meetings as provided by the by-laws, the first having been on October 13, 1904. These meetings have been well attended, thus providing evidence of the position of the Society as a factor in the dissemination of scientific information to the public. The average attendance was one hundred and twenty-five.

The following papers have been read:—

"Geology as an Experimental Science," by Professor Thomas A. Jaggar, Jr.

"A Practical Color System Based upon Photometric Measurements," by Mr. Albert H. Munsell.

"Sanitary Plumbing and Our Plumbing Laws, with Suggestions for Their Revision and Simplification," by Mr. J. Pickering Putnam.

"On Manila and the Philippines as They Are Today," by Mr. Desmond FitzGerald, C. E.

"Mont Pelée and the Eruptions of 1902; the Growth of the Wonderful Spine," by Mr. Edmund Otis Hovey.

"The Evolution and Improvement of Domestic Plants," by Dr. H. J. Webber.

"The Orientation of Buildings; or the Planning of Buildings and Streets with Regard to Light," by Mr. William Atkinson.

"The Hookworm Disease: a New and Important Parasitic Disease of Man," by Dr. Charles Wardell Stiles.

"Purification of Public Water Supplies in the Middle West," by Erastus G. Smith, Ph.D.

"Wireless Telegraphy," by Mr. John Stone Stone.

"The Abolition of Grade Crossings in Chicago by Track Elevation," by Mr. Charles B. Breed.

"The Physiography and Geography of Hawaii," by Professor George H. Barton.

"Storage Batteries," by Mr. Philip W. Davis.

"The Work of the Massachusetts Railroad Commission," by Mr. James F. Jackson.

Of the foregoing several were of special scientific importance, and awakened much interest, notably those by Messrs. Munsell, Putnam, Webber, Stiles, and Smith; and the papers by the two first named gentlemen have appeared in an expanded form in the TECHNOLOGY QUARTERLY.

The membership in the Society has remained practically constant, numbering three hundred and sixty-two.

The TECHNOLOGY QUARTERLY, under the editorship of Dr. Bigelow, has appeared at the regular intervals, and has contained the usual abstract of the Proceedings of the SOCIETY OF ARTS, together with such of the papers read before the Society as had been prepared in manuscript.

Various departments of the Institute have contributed, however, a number of important papers. Professor W. O. Crosby and Mr. G. F. Loughlin have begun a "Descriptive Catalogue of the Building Stones of Boston and Vicinity," considered in their geological and economic relations, with references to buildings in which they have been used. Professor Noyes has contributed a second part of his "System of Qualitative Analysis," and his address read before the International Congress of Arts and Sciences on the "Physical Properties of Aqueous Salt Solutions in Relation to the Ionic Theory." Other contributions from the Chemical Department have been an article by Professor Gill and Mr. Foster on "White Lead and Its Protecting Properties," one by Professor W. H. Walker and Mr. Bourne on the "Hydrolytic Enzyme Contained in Castor-Oil Seeds," and four contributions from the Laboratory of Sanitary Chemistry. From the Sewage Experiment Station, Mr. Phelps has contributed a paper on the "Interpretation of a Sewage Analysis,"

and Mr. S. DeM. Gage, of the Experiment Station in Lawrence, has published in the QUARTERLY the results of his studies on the "Bacteriolysis of Peptones and Nitrates." The activity of the Mining Department is shown by three valuable papers on metallurgical subjects by Professor Hofman and his students.

The Book Reviews have become a permanent and valuable feature of the QUARTERLY. During the year fifteen books have been reviewed in the QUARTERLY, chiefly by members of the Institute.

Respectfully submitted,

(Signed) GEORGE W. BLODGETT, *Chairman.*
EDMUND H. HEWINS.
CHARLES T. MAIN.
JAMES P. MUNROE.

THE ORIENTATION OF BUILDINGS AND OF STREETS IN RELATION TO SUNLIGHT

By WILLIAM ATKINSON, F.B.S.A.

(Read January 26, 1905)

"The Orientation of Buildings and of Streets in Relation to Sunlight" is a subject that I have been led to investigate in connection with the study of hospital architecture, but the results are equally applicable to the construction of all buildings occupied for residential purposes. If sunlight is essential for the recovery of the sick, is it not a still more powerful agent in the prevention of disease?

Unquestionably the first requisite for a hospital is abundance of sunlight. Not only the exterior wall surfaces of the buildings, but also the ground surfaces between and around them should have the direct rays of the sun for as long a time as possible each day.

"Second only to air is light and sunshine essential for growth and health; and it is one of Nature's most powerful assistants in enabling the body to throw off those conditions which we call disease. Not only daylight, but sunlight; indeed, fresh air must be sun-warmed, sun-penetrated air. The sunshine of a December day has been recently shown to kill the spores of the anthrax bacillus." (Galton, "Healthy Hospitals.")

Wall surfaces, especially brick walls, absorb a large amount of moisture during rains. This moisture is quickly dried out by exposure to sunlight, but is retained for a long time in walls which are not exposed to the sun, and creates an unhealthy condition; for dampness, with lack of sunlight, is a combination favorable to the growth of low forms of vegetable life, and should be avoided in hospital buildings. To secure sunlight in the fullest measure requires that the general plan of the buildings shall be carefully studied with this end in view.

In the study of existing hospitals I have found the greatest divergence in the orientation of the buildings. It therefore seemed to me advisable to make an investigation of this subject, and several years ago I obtained from the Harvard Observatory a table showing the position

of the sun for different periods of the year, and the data thus obtained are embodied in a sun chart which I will now show you.

Astronomy is not studied nowadays as it used to be, and perhaps it will be well to refresh our astronomical knowledge a little. These three diagrams show the position of the sun at each hour of the day for the three typical seasons of the year: December 21, the shortest day; March 21 and September 21, the equinoxes; and the longest day, June 21. There are several things that it will be convenient to fix in our minds. In the first place we see that the sun rises pretty nearly in the northeast in summer and sets pretty nearly in the northwest, and in winter the same distance southeast and southwest. At the time of the equinoxes it rises in the east and sets in the west.

Another thing convenient to remember is that in June about eight o'clock in the morning the sun is very nearly due east, and four o'clock in the afternoon very nearly due west. Then I would like you to observe the low altitude of the sun at noon in winter and the high altitude in summer. In one sense the period of the equinoxes may represent the average day because it is intermediate between the two extremes; but the declination of the sun is changing much more rapidly at those periods than it is in June and December. Consequently there are a great many more days which resemble December 21 in the winter and a great many more days in the summer which are typified by June 21 than there are days which are typified by March 21 and September 21. You will find, if you consult the almanac, that the length of days is changing very slowly around December 21 and June 21 and very rapidly at the time of the equinoxes. For instance, two weeks before December 21 the length of the day is only eight minutes longer than on December 21. So about June 21, two weeks before and after, the day is only a few minutes (about seven or eight) shorter than it is on June 21. On the other hand, two weeks before March 21 the day is forty minutes shorter than it is on March 21, and two weeks later, on April 4, it is forty minutes longer.

The time shown upon these diagrams is the time as shown by a sundial, which is different from our Eastern time, but the correction in each case can be made by consulting the almanac.

This slide illustrates what I call the "first lesson" in orientation. It represents a building square in plan. In one position it is set squarely with the meridian, and in the other the meridian passes through the diagonal. You can see that in the first the north wall

will obtain no sunlight at all during half the year, whereas in the second all four walls of the building will have more or less sunlight at all seasons of the year. The typical plan of the Swiss mountain dwelling is a square building set on the diagonal with respect to the

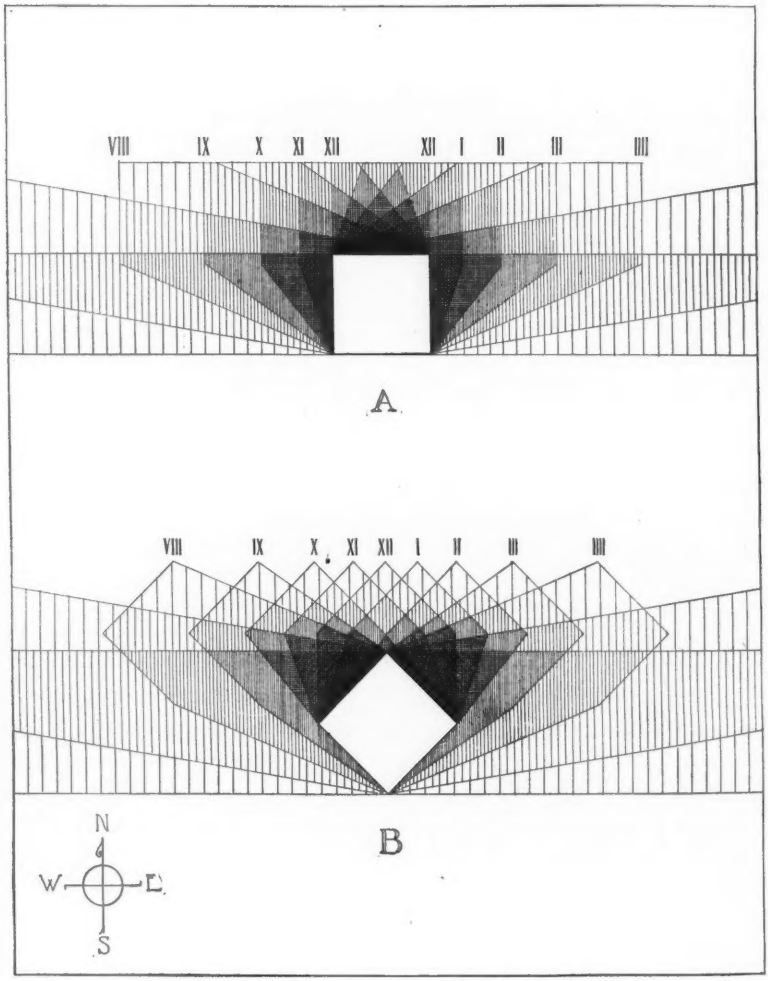


FIG. 1.—SHADOW DIAGRAM OF A CUBE

Giving the shadows cast by a cube from sunrise to sunset at the period of the equinoxes. Latitude of Boston, Mass.

meridian, and the living room is placed at the southern apex. Evidently the dwellers in these mountains learned to appreciate the value of sunlight at a very early date.

This diagram (Figure 1) represents the "shadow plan" of a cube placed in the two positions which I have shown. The shadows are drawn for each hour of the day and are superposed one upon another, and the degree of blackness corresponds roughly to the length of time in which that particular spot is in shadow during the day; the full black in that case represents an area which is in sunlight for less than one hour. You will observe that in this position (A) of the cube there is a very considerable triangular area here, much larger than in this one (B), which has very little sunlight. In other words, a square building placed in the latter position shades the ground around it very much less than a similar building placed in that position (A). The diagram suggests another and better method of representing these matters by means of curves. The intersections of the various shadows will determine one series of points, each of which is in shadow for exactly one hour, and another series of points in shadow for two hours, and so on; and by joining these points we obtain a series of curves which may be called the "shadow curves" of the cube.

The next diagram (Figure 2) will show these shadow curves for March 21 and September 21. In each area the numerals indicate the number of hours during which that area is without sunlight. Similarly we might draw such a shadow diagram for a building of any shape by pursuing the same method, but practically we find that almost all buildings, especially hospitals, are composed in their elements of two wings forming an L, or three wings forming a U-court. Especially are hospitals composed of U-courts, so that if we study the U-court we have accomplished the greater part of the necessary study.

If we study the shadow plan of such a U-court (Figure 3) we shall find that the most advantageous position is that in which the court faces southeast or southwest, and the least advantageous is that in which the court faces the north; and yet how often do we see buildings constructed on this plan with the court facing the north.

So far we have considered the outside surfaces of the building and the surface of the ground around it. We now proceed to study the interior lighting of buildings. This diagram (Figure 4) illustrates the subject of windows. These various patches of different shapes represent cross sections of a prism of light rays passing through a window

8 feet high, $3\frac{1}{2}$ feet wide, and thickness of 1 foot in the wall. Now by multiplying the area of any one of these figures by the length of time during which the sun is shining through the aperture of that shape, we

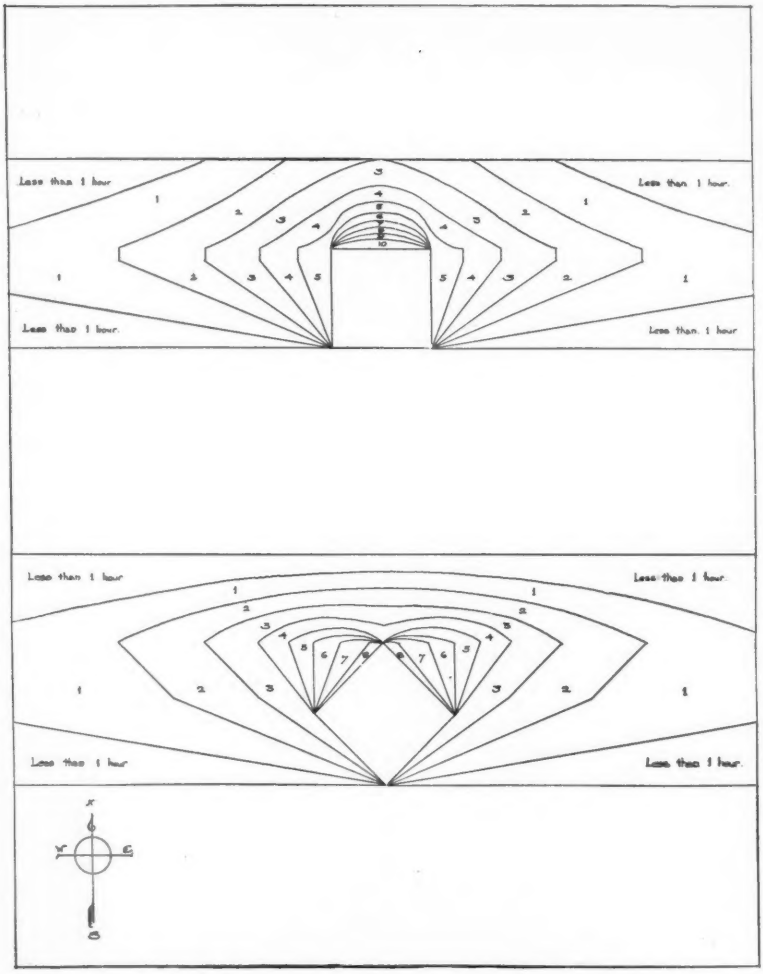


FIG. 2.—SHADOW CURVES OF A CUBE

This diagram is constructed from the preceding. The numerals indicate the number of hours during which each area is in shadow: *i. e.*, the areas marked 1 are in shadow from one to two hours; those marked 2 from two to three hours, and so on.

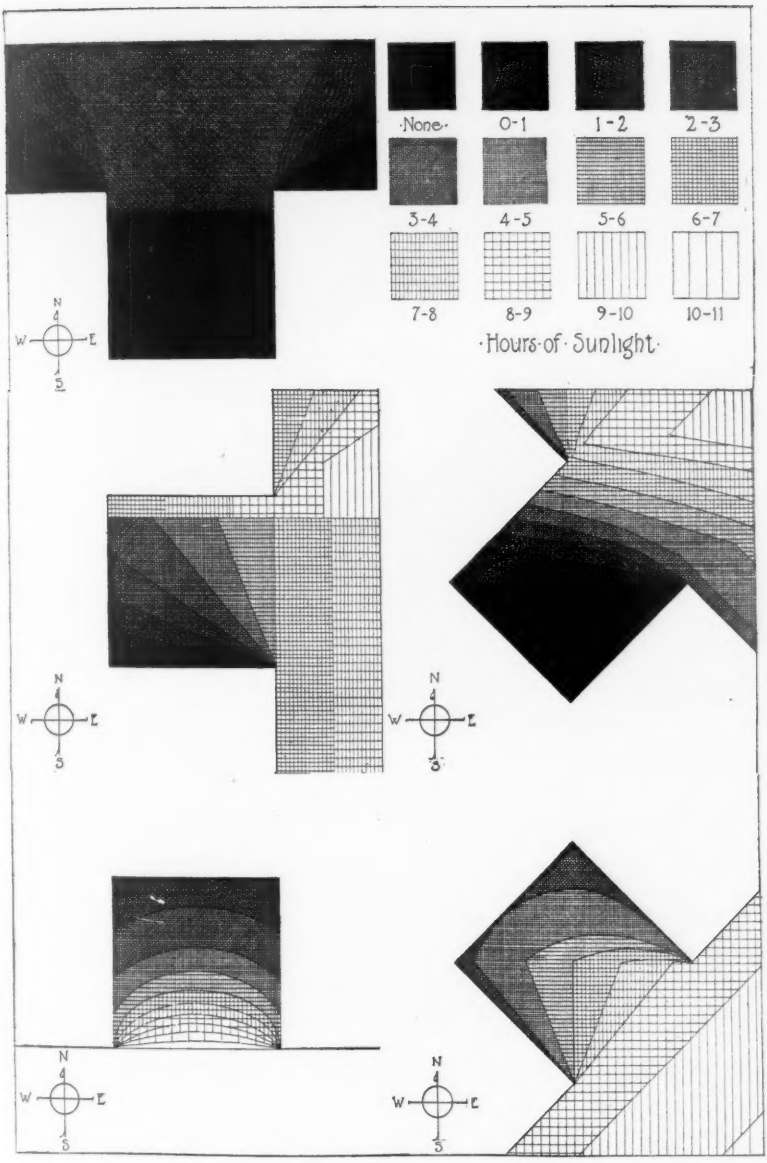


FIG. 3. — SHADOW DIAGRAMS OF A U-COURT

Representing the distribution of sunlight upon the ground surface of a U-court facing north, northeast, east, southeast and south. The height of the court is supposed to be equal to the width and depth. The depth of shade at any point indicates the length of time that point is in shadow, corresponding to the table of tints in the upper right-hand corner. Latitude of Boston, Mass. Time: March and September.

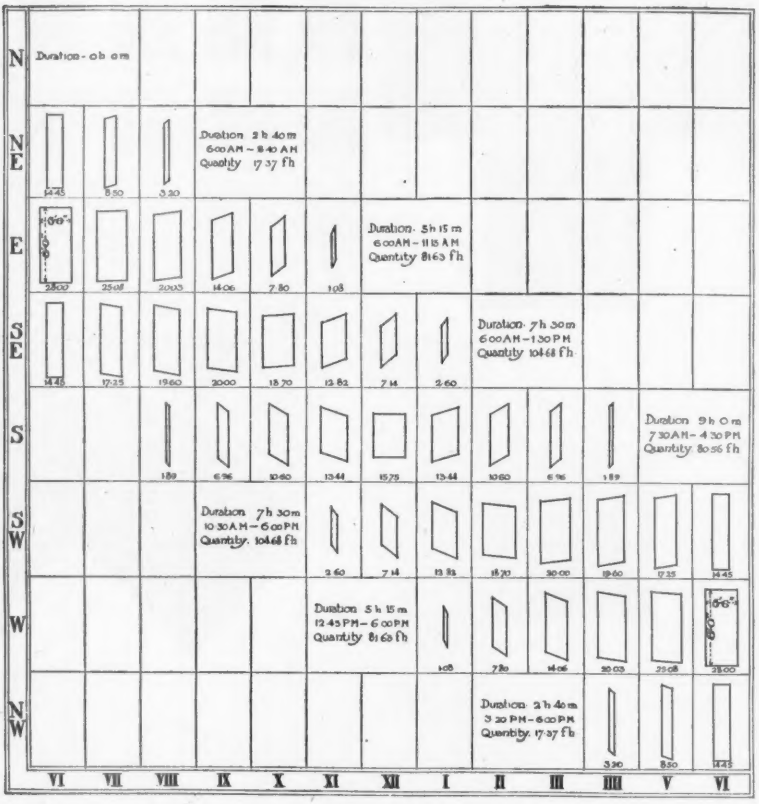


FIG. 4. — WINDOW ASPECTS

Giving the aspect of window openings as presented to the sun, for windows facing in various directions. Size of opening, 3′ 6″ wide, 8′ 0″ high, 1′ 0″ thick. The numerals below each figure give the area of the cross-section in square feet. The numerals following the word "quantity" give the amount of sunlight, in sun-hours, passing through the aperture during the day. The letters in the left-hand column indicate the direction in which the window faces. The Roman numerals at the bottom give the hour of the day for which each figure is drawn. Latitude of Boston, Mass. Time: March and September.

shall obtain what I call the "quantity" of sunlight expressed in "sun-hours," the sun-hour being the amount of sunlight received by a surface 1 foot square exposed to the sun for one hour. This diagram (Figure 5) illustrates the illumination of the floor through the window, and if the floor of that room were covered with a carpet dyed in aniline colors we should find at the end of the day the unshaded portion somewhat faded,

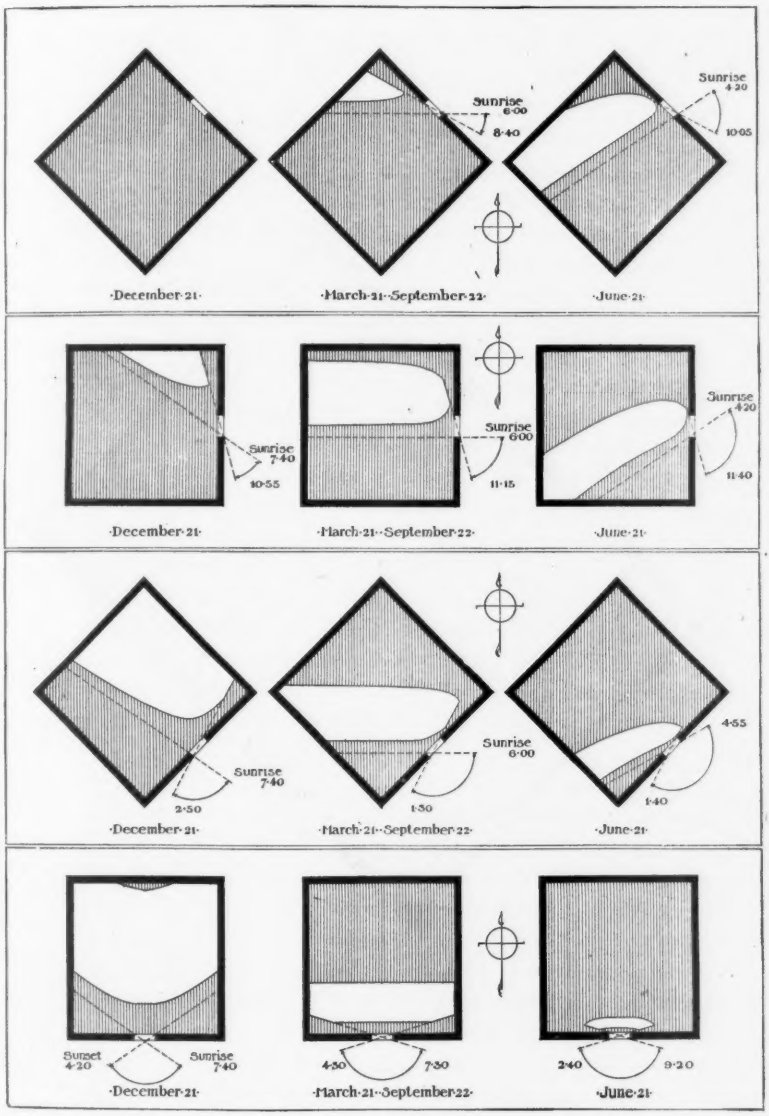


FIG. 5. — WINDOW ILLUMINATION

Representing the floor area of an apartment 24′ 0″ square, illuminated by a single window 3′ 6″ wide, 8′ 0″ high, 1′ 0″ thick, sill 2′ 0″ above floor, facing northeast, east, southeast and south. Latitude of Boston, Mass.

because that represents the area of the floor which has received sunlight during the day. The diagram is drawn for the four typical seasons of the year. The south window is one of extremes; in winter it transmits a great amount of sunlight, but in summer, owing to the great altitude of the sun, this small patch of floor is all that receives sunlight during

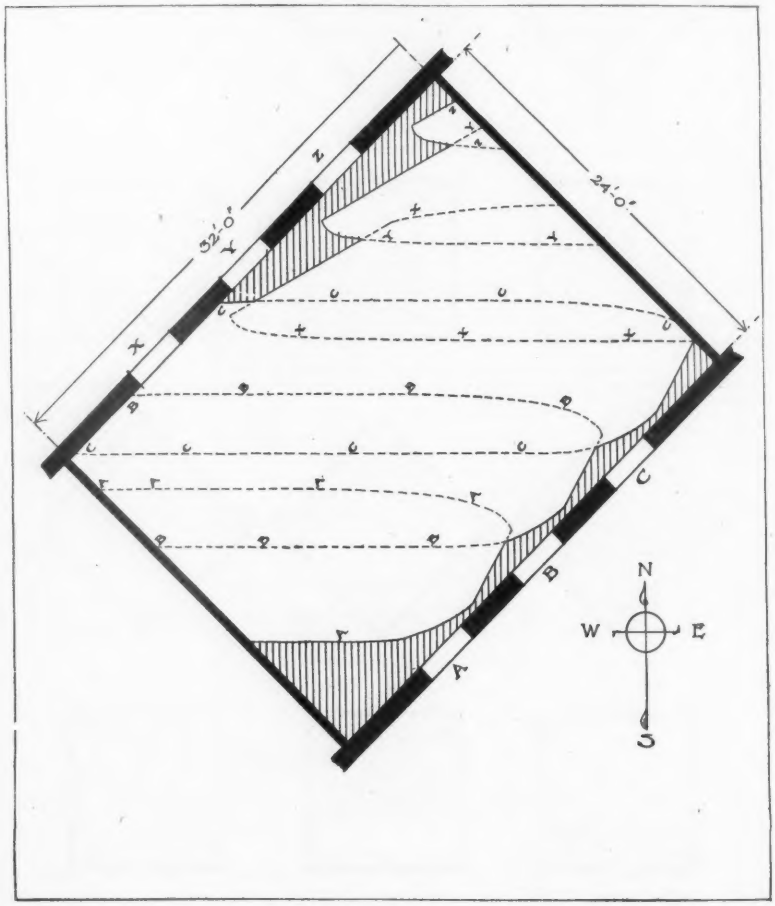


FIG. 6.—WINDOW ILLUMINATION

Representing the floor area of an apartment 24′ 0″ wide and 32′ 0″ long, lighted by three windows on each side, facing northwest and southeast, respectively. Size of windows as in the preceding diagram. The letters indicate the area illuminated by each window. Latitude of Boston, Mass. Time: March and September

the day; so the south window is a very cool one in summer and a very warm one in winter. By superposing these areas on any given plan we can obtain the floor illumination of a room of any shape and with windows variously placed. For instance, this diagram (Figure 6) represents an open ward in a hospital.

So far we have considered buildings only, but buildings (in cities, at least) are generally governed — that is, the orientation of the buildings — by the direction of the streets on which they are built, and it is to the matter of streets that I propose to pay my particular attention this evening; and in the study of streets there are two matters to be considered, sunlight and skylight. The direction of the street affects the sunlight particularly; the height of the buildings upon it affects both the sunlight and the skylight. Skylight comes from all directions of the heavens; sunlight from only one direction. The English have appreciated the value of both for a long time. I have recently been studying the "Law of Ancient Lights," so called; it dates from a period far back in the time of the Richards. In 1623 Parliament passed a statute in regard to this matter, which provides that if an owner or tenant of a building has enjoyed light for a space of twenty years he thereby acquires a right in the property of his neighbor over which that light comes. "*Cujus est solum ejus est usque ad cœlum*" is an ancient maxim of English law, and in the words of an English writer, "An interference with the space superincumbent on a man's land is an injury for which the law provides a remedy." As an example of the way in which the law works in England, I will describe a typical case.

The plaintiff, a sculptor, had a studio on a narrow lane in London, Mill Hill Street, 37 feet wide. He had occupied this studio for twenty years, and his lease had still six years to run. Across the way was a building 37 feet high, occupied by a firm of silk merchants. The latter, to provide more room for their business, were preparing to add another story to their building. But the sculptor brought suit on the ground that his light would be seriously interfered with, and succeeded in obtaining a perpetual injunction against the silk merchants forbidding them to increase the height of their building, and the judge, in delivering his opinion, spoke as follows: —

"The case is proved, in my opinion, on behalf of the plaintiff. He has proved a statutory right to the enjoyment of his light undiminished. In my opinion, they have no more right to take away the light which the plaintiff has been enjoying than they have to take away the front wall of his house."

Now this may seem very strange doctrine to Americans, but it is well for us to ponder it. The English are very jealous of the rights of the individual owner in these matters. One reason for this may be the custom of having long leases in England. Now in this country when a man has an office down town he very seldom takes a long lease of it. If his neighbor puts up a tall building across the way and shuts off his light, he rents another office somewhere else, generally in a new sky scraper, where his light will probably not be interfered with for several years, at least.

As in the forest those trees flourish best which overtop their neighbors, so in our American cities the sky scraper enjoys an advantage of light and air at the expense of the lower and more ancient buildings.

We will now proceed to investigate the distribution of sunlight in streets running in various directions and of different sections.

The next three slides (Figures 7, 8, and 9) illustrate the distribution of sunlight in streets running north and south, east and west, and southeast and northeast, respectively, for the four typical periods of the year, and for streets in which the height of the buildings is in various proportions to the width of the street.

The amount of sunlight in the street is represented by means of curves, and the method of obtaining these curves I shall describe later on. Each curve represents a series of points in the cross section of the street, each of which is in sunlight a given number of hours. The curve is a convenient way of representing the amount of sunlight. It enables us to present in a single diagram a result combined from a great number of separate diagrams.

Now in the first place we can see that the street running east and west is the very worst of all in winter. Notice the direction of the sun's rays at noon. They penetrate a very small distance down into the street. In summer, when the sun is more nearly overhead, the street gets a great deal more sunlight. It is a street of extremes, cold in winter, hot in summer. The diagonal street is very much better off. The north and south street receives in winter the greatest amount of sunlight; at other times of the year the diagonal street is pretty nearly equal to it. I wish you to observe that in a system of streets running at right angles to each other the best method is to lay out on the diagonals southeast-northwest and southwest-northeast. In most American cities the streets are laid out north and south, east and west. I suppose

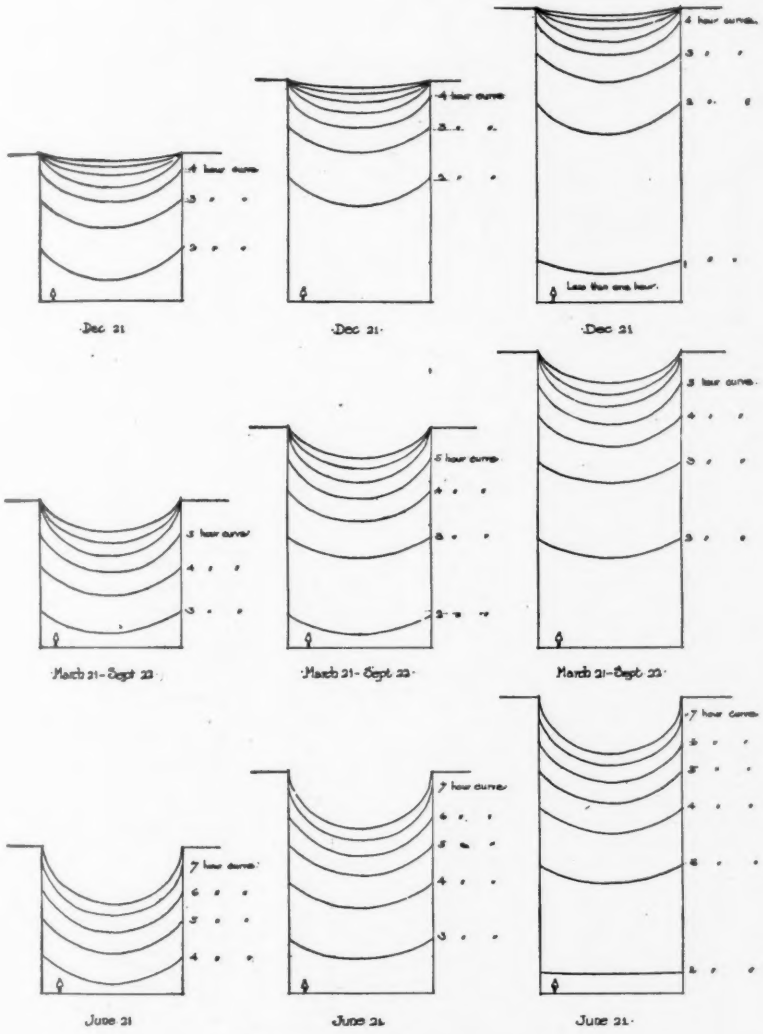


FIG. 7.—STREET ILLUMINATION

Representing the cross-section of a street running north and south. In the left-hand column the height of the buildings is equal to the width of the street; in the central column one and one-half times the width of the street; and in the right-hand column twice the width of the street. Latitude of Boston, Mass.

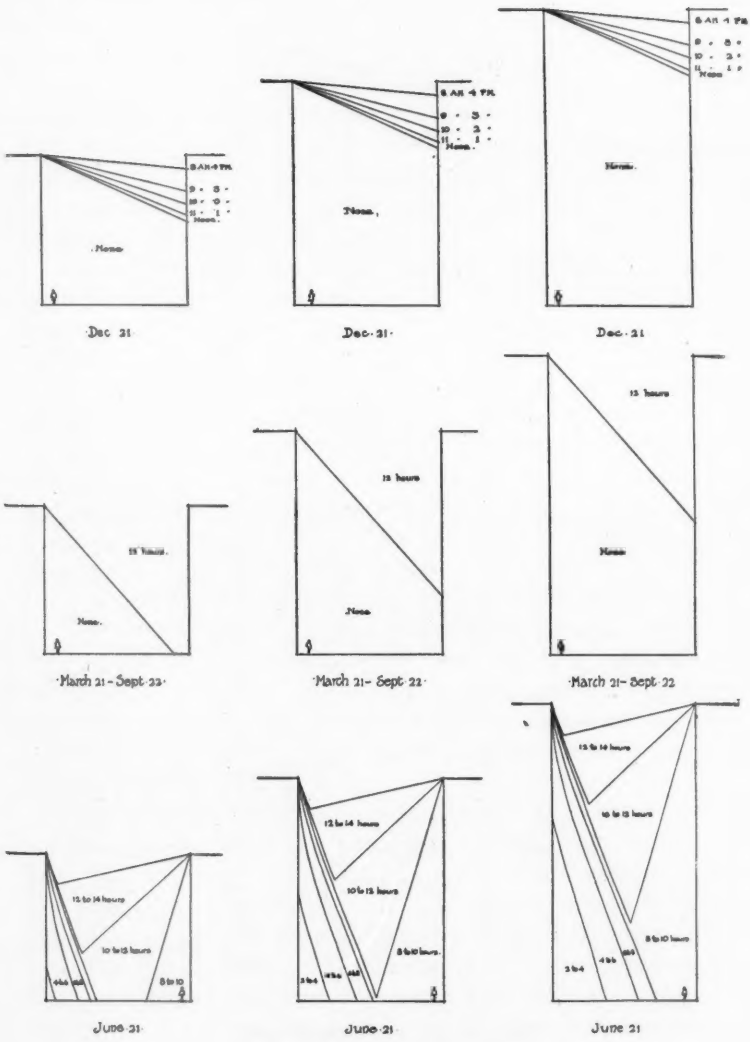


FIG. 8.—STREET ILLUMINATION

Representing the cross-section of a street running east and west, looking west. The height of the buildings bears the same relation to the width of the street as in the preceding diagram. Latitude of Boston, Mass.

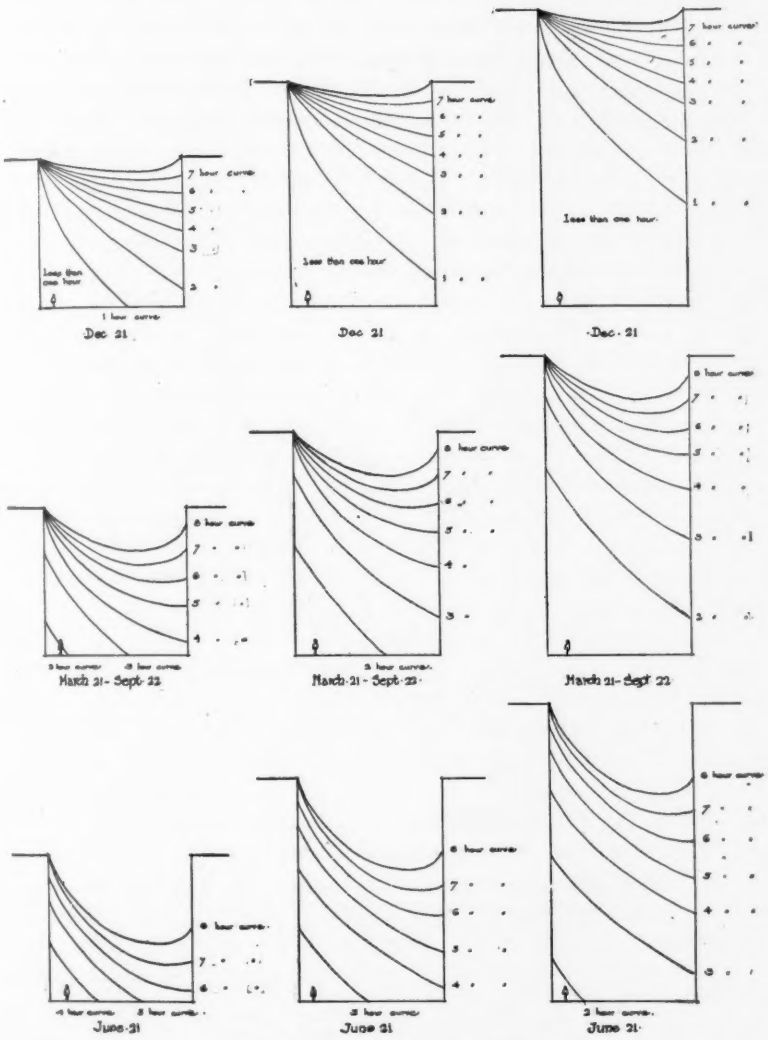


FIG. 9. — STREET ILLUMINATION

Representing the cross-section of a street running southeast and northwest, looking northwest, or of a street running northeast and southwest, looking southwest. The height of the buildings bears the same relation to the width of the street as in the two preceding diagrams. Latitude of Boston, Mass.

this is because the engineer first runs his meridian, and then plans the streets to follow it. Unfortunately, the principal streets of our Back Bay run pretty nearly east and west; the cross streets north and south.

The method of obtaining the light curves I will explain by the next slide (Figure 10). This is a cross section of a street. Here is the

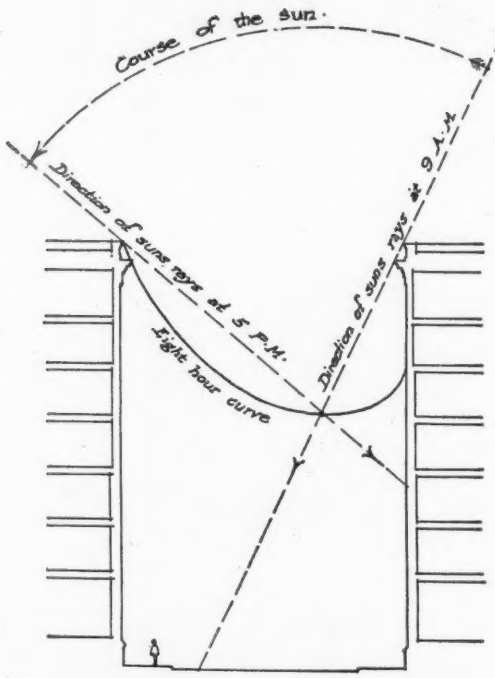


FIG. 10. — STREET ILLUMINATION

Illustrating the method of obtaining the light curves of the three preceding diagrams. Street running southeast and northwest, looking northwest. Latitude of Boston, Mass. Time: June 21.

direction of the sun's rays at nine A.M.; here, eight hours later, at five P.M. This point (at the intersection) comes into sunlight at nine o'clock and into shadow at five o'clock. In other words, it has been in sunlight for eight hours. If we connect a series of such points we shall have our curve, in this case the eight-hour curve.

Where the buildings are high in proportion to the width of the street the light at noon comes only a short distance down from the

top. Where the buildings are equal in height to the width of the street on the average day of the year, at the time of the equinoxes, in a street running east and west the sun's rays will fall upon the ground surface at about the edge of the sidewalk. That explains, I suppose, one reason why, in a great many European cities, that proportion has been deemed to be the proper one for the height of buildings. Of course, as the latitude varies the diagrams will vary, these all being drawn for the latitude of Boston. In England, although in summer the days are very much longer, the sun travels very much nearer the horizon than it does with us. That may be one reason why these questions have been considered of more importance there than in this country. As we go south, of course, the sun travels nearer the zenith.

The superiority of a system of streets running on the diagonals was pointed out many years ago by Horace Bushnell in an essay on the planning of cities, but his teachings have apparently been forgotten.

In studying the problem of tall buildings we have to consider, not the effect of one building only, because that is insignificant, but we must consider the street as if built up to a uniform height equal to that of the tallest building. This diagram (Figure 11) will show us the amount of ground which would be shadowed in December by a single sky scraper supposed to be built on the site of the Hotel Bristol across the street. This imaginary structure is supposed to be 300 feet high. That represents a fair average height for a modern New York sky scraper, of course much higher than any building we have in Boston. We are indebted to Mr. Minot and the others who drew up our original code of building laws that we have been spared such an infliction.

Two things are observed. Of course you understand that if that building were half as high these shadows would be just half as long. You will note that the shadows extend across Commonwealth Avenue. In other words, if the north side of Boylston Street were built up solid with buildings of this height the whole of Commonwealth Avenue would be in shadow at all times during the day at this period of the year.

We must not consider these tall buildings separately. We must consider them as if the whole street were built up with them, because that is the condition to which we are rapidly coming in cities in this country. In making building laws and planning streets we should look into the future and not merely regard the present. I have a great respect for the American engineer. He has accomplished a

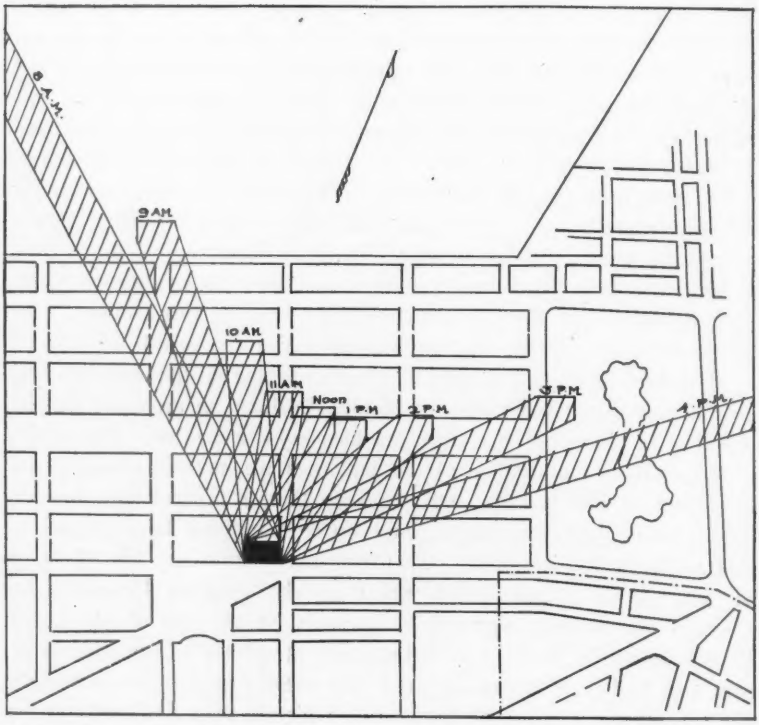


FIG. 11. — SHADOWS OF A SKY SCRAPER

Representing the shadows which would be cast in December by a building 300 feet high, erected on the site of the Hotel Bristol, Boston, Mass. Scale of drawing about 833 feet to an inch.

great many wonderful things in the construction of tall buildings. Ways have been devised for preventing corrosion of the steel in these buildings, for making them safe against fire; and even if the fire engines cannot throw their streams to such a great height there can be standpipes to make them perfectly safe. If the buildings are large enough to have two staircases they can be planned in such a way that if they take fire there is a good chance for every one to escape before they burn up. All difficulties have been overcome except one — the American engineer has not yet invented a way of making these buildings transparent, and I do not believe he ever will.

The next slide is a view of the Tremont Building. Not a sky

scraper in the sense in which the word is generally used, but for Boston a tall building. What I wish to point out is the shadow cast upon this building by Tremont Temple across the way. If the block to the east of Tremont Temple were built up to a height equal to that building, this shadow would extend out to the edge of the Tremont Building and completely shut out the light from these stories at the hour of the day at which this photograph was taken, which I judge was some time during the forenoon in summer. Passing this building at a quarter past ten the other morning, I noticed the shadow cast by the Paddock Building farther east, and it extended up to the top of the seventh story windows and across nine of them in this direction. The point to be emphasized is that tall buildings materially interfere with each other's light. The Tremont Building is placed opposite a permanent open area, so it will never suffer from that direction, but all buildings are not so fortunately placed as this one.

A bill has recently been introduced into the legislature, on petition of your Professor Sedgwick, which proposes to limit the height of buildings in the state of Massachusetts outside of Boston. Outside of Boston very few buildings have been built exceeding 100 feet in height. I suppose they could be counted on one's fingers. Therefore if such a law should be passed now it would not work injuriously; it would bear equally upon every one.

Such is not the case in Boston. Here we have a condition, not a theory. In the down-town section we have a great many high buildings; in the residential section but a few. Therefore the problem is a very difficult one. It is hard to frame a law which will not do injustice to some one. It is commonly considered impracticable further to limit the height of buildings in the down-town sections, because so many of them are already built up to 125 feet; but last winter a law was passed, the "A and B law," so called, which empowered the Mayor to appoint a commission to divide the city into two sections, residential and business. In the residential section no building is to exceed 80 feet. The commission have drawn a line. It is, of course, impossible to divide the residential district from the business section by a hard and fast line. In reality there exists no line such as this. The division is more gradual. The business district shades off imperceptibly into the residential. Therefore the drawing of such a line must produce more or less dissatisfaction. Where it passes through the centre of a street a building on one side cannot be

above 80 feet; where it passes through a block the owner on the business side of the line can go up 45 feet higher than his neighbor on the other side. This, of course, produces dissatisfaction in the mind of the owner who is on the wrong side of that line. The commission have recommended that the limit of 80 feet is too low, and that it should be raised to 100 feet in some parts of the residential districts. That will make the disparity of conditions less.

I believe it to be entirely practicable to make an amendment to that law which will eliminate to a large extent the dissatisfaction. It is possible to frame a law which will shade down that limit of height imperceptibly from 125 feet in business districts to 100 feet in residential districts. Several ways have been suggested of doing this, and doubtless they will be brought to the attention of the legislature this winter. Uncertainty in building laws produces bad conditions in business, and it is to be hoped that this winter the legislature may arrive at some plan which will eliminate all special legislation, which can be made permanent and satisfactory to every one. We have been trying for some years, groping in the dark, as it were, to solve this question, and the results have not been particularly fortunate. The Copley Square law gave a great deal of dissatisfaction — 100 feet on one side and 90 feet on the other, with no very good reason for it. There is another law which empowers the Park Commission to restrict to 70 feet on the parkways, and yet there is no place where a tall building looks so well as upon the borders of a park. It is to be hoped that both of these laws may be repealed this winter, and some uniform law be made to take their place.[1]

We can learn something in this matter, I think, from the bill which has been introduced into the legislature on the petition of Professor Sedgwick. That proposes for the state a maximum limit of 100 feet, and a further limitation for the façade of buildings of one and one-fourth times the width of the street upon which they are built. (See Appendix A.)

This diagram (Figure 12) contrasts the existing law in Massachusetts with the proposed law. It represents in cross section a street 60 feet wide running north and south. The direction of the sun's rays is shown at the moment when they first reach the surface of the street and again when they leave the surface, at the period of the equinoxes.

[1] See Appendix B for legislation of 1905.

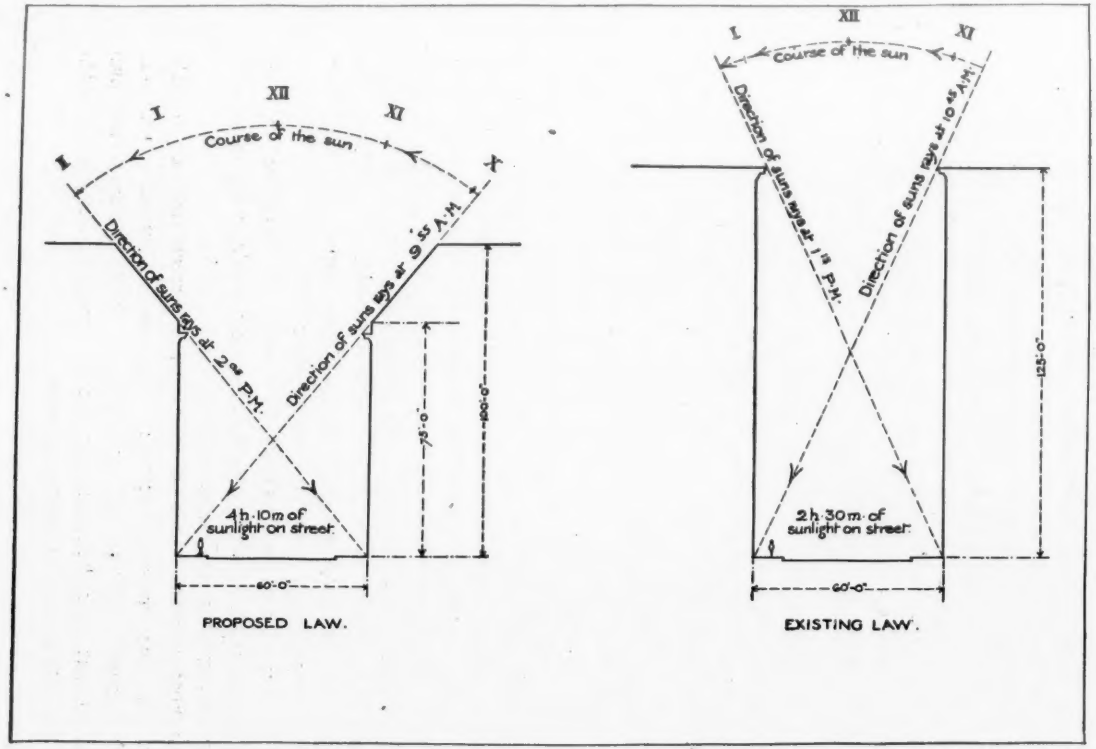


FIG. 12. — HEIGHT OF BUILDINGS

Contrasting the existing law in Massachusetts with the proposed new law. Representing the cross-section of a street running north and south. Latitude of Boston, Mass. Time: March and September.

The proposed law provides in effect that no portion of the building, excepting chimneys and other similar constructions, shall be built beyond a sloping line, drawn from the opposite side of the street and rising at an angle of $1\frac{1}{4}$ to 1 (about 52°).

In its general form we believe this law to be correct. I think every one will admit that the height of a building should bear some reasonable relation to the width of the street upon which it is placed. It also should be recognized that it is the upper part of the front wall of the building which is most effective in cutting off the sunlight from the street.

The working of this law would naturally result in the adoption of the sloping roof, or in the stepping back of the building in this way, or in some cases of the whole building being set back from the street line. The sloping roof has not been used very much in Boston, inasmuch as the present building laws do not allow an elevation of more than 20° in pitch. The views which follow will illustrate some of the sloping roofs in different cities in Europe and how beautiful they can be made architecturally. Here is a hotel in Paris. The next is a street in Marseilles, which illustrates very well the sloping roof and the comparatively reasonable height of the buildings, which in this case I should judge was about one and one-fourth times the width of the street. It also illustrates another point, the broad sidewalks which they enjoy in those European cities. Few things are more wearing to the nerves than to hurry through our narrow Boston sidewalks after a train, pushing along through the crowd. It is really a serious matter, and in Boston we suffer more from narrow sidewalks than from narrow streets. New York is very much better off in this respect.

The next view shows a building in Lyons. It illustrates the stepping back of which I spoke; and the next view, which is the last, shows us the sloping roofs of Vienna.

In Boston we have suffered from narrow streets and narrow sidewalks, but these errors are mistakes of the past. It should be the work of the present, profiting by experience, to build buildings and plan streets so that they shall not shut out the fresh air and the sunlight from the Boston of the next generation.

Appendix A

House Bill No. 775, Accompanying the Petition of William T. Sedgwich for Legislation to Provide for the Protection of Streets and Property Owners Against the Encroachments of High Buildings upon Light and Air.
Cities. January 26

Commonwealth of Massachusetts

In the Year One Thousand Nine Hundred and Five

AN ACT

To provide for the Protection of the Public Health and of Streets and Property Owners against the Encroachments of High Buildings upon Light and Air.

Be it enacted by the Senate and House of Representatives in General Court assembled, and by the authority of the same, as follows:

Section 1. The following restrictions shall apply to all buildings hereafter erected or altered in the state of Massachusetts outside of the city of Boston, with the exception of grain elevators, coal elevators, standpipes, water tanks, sugar refineries and buildings located more than fifty feet from any public way, street, park or adjoining property line.

Section 2. No part of any such building, save the exceptions enumerated in section four, shall be erected to a height above the grade of the street nearest to and opposite such part exceeding one and one-quarter times the least horizontal distance of such part from the farther side of said street: *provided, however*, that no part of any such building, save the exceptions enumerated in section four, shall be erected to a height exceeding one hundred feet above the grade of the lot vertically below such part. But in the case of a building having a corner frontage upon two or more streets of unequal width, the limitation of height first above described shall be made as if all of said streets were of a width equal to that of the widest of them.

Section 3. In the application of this act, all streets of less width than forty feet shall be considered as of a width of forty feet, and all streets or portions of streets upon which buildings may be erected upon one side only shall be considered as of a width of eighty feet.

The term "street," as used in section two of this act, shall not apply to any private way, nor to any public way for the use of foot passengers only, nor to any public way constructed and used principally as a means of access to the rear entrances of the buildings built upon it.

Section 4. The limitations of height above described shall not apply to steeples, towers, domes, cupolas, belfries or statuary, not used for purposes of habitation; nor to chimneys, open balustrades, skylights, ventilators, flagstaffs, railings, weather-vanes, soil-pipes, steam-exhausts, signs, roof houses not exceeding twelve feet square or twelve feet high, nor to other similar constructions such as are usually erected above the roof line of buildings.

Section 5. The supreme judicial court or the superior court shall have jurisdiction in equity to enforce the provisions of this act and to restrain the violation thereof.

Section 6. This act shall take effect upon its passage.

(This act failed of passage.)

Appendix B

Commission on Height of Buildings in the City of Boston

[Order of July 21, 1905]

The Undersigned having been appointed on May 25, 1905, by the Mayor of the City of Boston under the provisions of chapter 383 of the Acts of 1905, members of a commission to determine, in accordance with the provisions of said act, the height of buildings within the district designated by the Commission on Height of Buildings in the City of Boston as District B, in accordance with chapter 333 of the Acts of 1904, and having given notice and public hearings, hereby determine and order that in any of the Districts B, as designated by said Commission on Height of Buildings, in its order of July 5, 1904, as amended by its order of December 3, 1904, the said orders being recorded with Suffolk Deeds, Book 2976, page 45, and Book 3008, page 129, respectively, buildings may be erected on streets exceeding sixty-four (64) feet in width, to a height equal to one and one-quarter times the width of the street upon which the building stands; and, if situated on more than one street, the widest street is to be taken, the height to be measured from the mean grade of the curbs of all the streets upon which the building is situated, and not exceeding one hundred (100) feet, in any event.

If the street is of uneven width, its width will be considered as the average width opposite the building to be erected.

The width of a street shall be held to include the width of any space on the same side of the street upon which a building stands, upon or within which space no building can be lawfully erected by virtue of any building line established by the Board of Street Commissioners or the Board of Park Commissioners acting under general or special laws.

All streets or portions of streets upon which buildings may be erected on one side only shall be considered as of a width of eighty (80) feet as to that portion upon which buildings may be erected on one side only.

In the case of irregular or triangular open spaces formed by the intersection of streets, the width of the street shall be taken as the width of the widest street entering said space at the point of entrance.

No building shall, however, be erected on a parkway, boulevard or public way on which a building line has been established by either of said Boards acting under general or special laws to a height greater than that allowed by said general or special laws, nor otherwise in violation of section 3 of said chapter 383, Acts of 1905.

No building shall be erected to a height greater than eighty (80) feet unless its width on each and every public street upon which it stands will be at least one-half its height.

Nothing in this order shall be construed as affecting any condition, or restriction imposed by deed, agreement or by operation of law on any property in said Districts B.

The said Commissioners further provide that buildings may be erected to a height not exceeding one hundred and twenty-five (125) feet in that portion of the District B as established by the Commission on Height of Buildings in its order dated December 3, 1904, recorded with Suffolk Deeds, Book 3008, page 129, which lies fifty (50) feet westerly from the boundary line running from Columbus Avenue to the centre of Boylston Street, separating said District B from District A, as established by said order; *provided, however*, that said portion of District B is owned by the same person or persons who own the adjoining premises in District A.

IN WITNESS WHEREOF, the undersigned, being a majority of said commission, the third member (Nathan Matthews) being in Europe, hereto set their hands, this twenty-first day of July, 1905.

JOSEPH A. CONRY,
HENRY PARKMAN,
} *Commission on Height of Buildings in the City of Boston.*

BOSTON, July 21, 1905.

Then personally appeared the above-named JOSEPH A. CONRY and HENRY PARKMAN and acknowledged the foregoing instrument to be their free act and deed.

Before me,

JOHN S. ADAMS,
Justice of the Peace.

CONTRIBUTION FROM THE DEPARTMENT OF FOOD AND DRUG INSPECTION OF THE MASSACHUSETTS STATE BOARD OF HEALTH

THE DETECTION AND DETERMINATION OF ETHYL AND METHYL ALCOHOLS IN MIXTURES BY THE IMMERSION REFRACTOMETER[1]

BY ALBERT E. LEACH AND HERMANN C. LYTHGOE

THE use of wood alcohol in various preparations which come within the domain of the public analyst for examination is apparently on the increase. It is especially to be looked for as an adulterant in medicinal preparations, liniments, tinctures, and in all varieties of flavoring and other extracts high in alcohol. In Massachusetts we have found methyl alcohol in various pharmaceutical preparations, such as tincture of iodine, and in lemon and orange extracts.

Existing methods for the detection of wood alcohol, with one or two exceptions, are extremely unsatisfactory. Most of the older methods, such, for example, as the potassium permanganate test, depend upon the presence of acetone in the methyl alcohol. With the improved refining processes used at the present day, wood alcohol is readily obtainable free from more than traces of acetone, so that it is impossible to detect it from ethyl alcohol by its odor. Crude wood alcohol with acetone present in marked degree is frequently capable of being indicated even in mixture with ethyl alcohol by the sense of smell. It is the refined or deodorized methyl alcohol, sold under a variety of trade names, such as Columbian Spirits, Hastings Spirits, Colonial Spirits, purified wood alcohol, etc., that one finds as an adulterant of tinctures, extracts, and beverages.

The most practical method hitherto used for the detection of methyl alcohol is that of Mulliken and Scudder,[2] which depends on the oxida-

[1] Read at the thirty-second general meeting of the American Chemical Society, in Buffalo, New York, June 23, 1905. Printed also in the Journal of the American Chemical Society.

[2] American Chemical Journal, 1900, XXIV, p. 444.

tion of the methyl alcohol in the sample to formaldehyde by the use of a red-hot spiral of copper wire, ***using, however, the hydrochloric acid and milk test for the detection of formaldehyde in the oxidized solution.***[1]

Attention is further called to the German official process of Windisch,[2] a color reaction depending on the transformation of the methyl alcohol to methyl violet.

Methods for quantitative determination of wood alcohol are even more rare. Duprey[3] has suggested a method of concentrating the alcohol by repeated distillation, after which part of the final distillate is oxidized to acetic acid, the latter being titrated with alkali, while the alcohol is determined in the other portion of the distillate from the specific gravity. Both methods with pure ethyl alcohol should give concordant results, whereas in presence of methyl alcohol a lower result is obtained by the oxidation process.

The specific gravity of absolute methyl and ethyl alcohol is practically identical, and it is also true that when mixed with varying proportions of water the specific gravity of both alcohols is so nearly the same (with the same proportions of water in each) that the same tables for computation of percentage of alcohol from the specific gravity may be used in one case as in the other.

A very important physical constant, however, which we have found to differ most widely in the two alcohols is the index of refraction, and it is on this property that we base our method for the detection and determination of methyl alcohol.

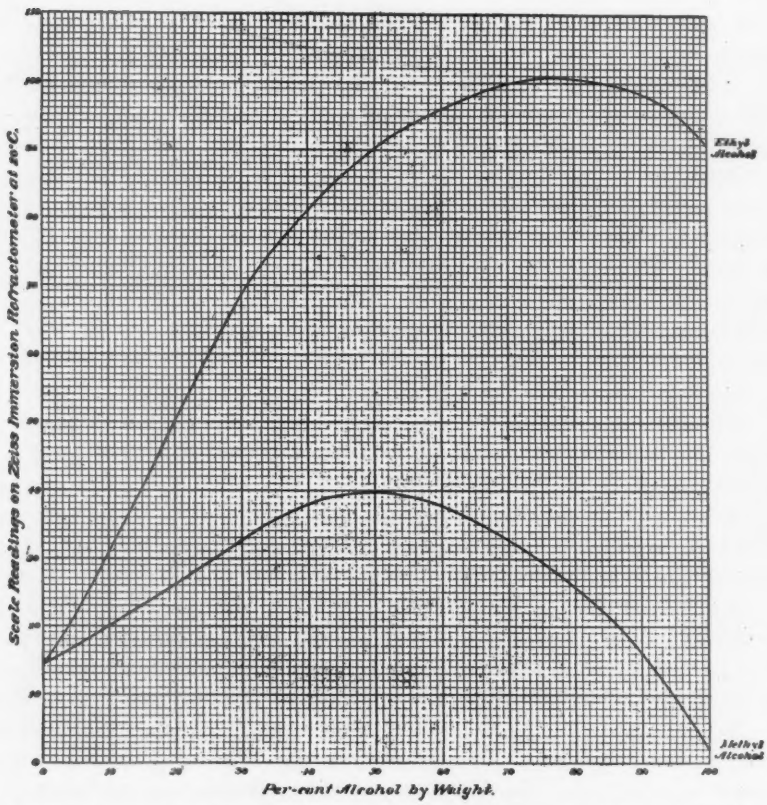
We use for this purpose the somewhat recently devised immersion refractometer of Zeiss. This instrument was fully described in a former paper by us.[4] To illustrate the wide difference in refraction between the two alcohols, the strongest commercial ethyl alcohol found on the market (the alcohol of the United States Pharmacopœia, which contains 91 per cent. of absolute alcohol by weight) gives a reading with the immersion refractometer of 98.3 at 20° C., while the reading of methyl alcohol of 91 per cent. strength by weight is 14.9. Fifty per cent. ethyl alcohol by weight has a refraction on the immersion refractometer of 90.3, while the same strength (50 per cent.) of methyl

[1] Annual Report Massachusetts State Board of Health, 1897, p. 558; Leach, Food Inspection and Analysis, p. 666.

[2] Vereinbar. z. Unters. v. Nahr. u. Genussm, Heft II, p. 130.

[3] Analyst, I, p. 4.

[4] Journal American Chemical Society, 1904, XXVI, p. 1196.



CURVES SHOWING THE PERCENTAGE BY WEIGHT OF ETHYL AND METHYL ALCOHOLS, RESPECTIVELY, CORRESPONDING TO THE SCALE OF THE ZEISS IMMERSION REFRACTOMETER. See Table I.

alcohol refracts on the instrument at 39.8, all readings being made at 20° C. From this wide variation it is readily seen that there is no trouble in detecting even small amounts of methyl alcohol in mixtures. Table I shows the percentage by weight at 20° C. of the two alcohols corresponding to each degree of scale reading on the refractometer.

TABLE I—Percentage by Weight of Ethyl and Methyl Alcohols Corresponding to Scale Readings on Zeiss Immersion Refractometer at 20° C.

Scale reading 20°.	Per Cent. Alcohol by Weight.		Scale reading 20°.	Per Cent. Alcohol by Weight.		Scale reading 20°.	Per cent. ethyl alcohol by weight.	Scale reading 20°.	Per cent. ethyl alcohol by weight.	
	Methyl alcohol.	Ethyl alcohol.		Methyl alcohol.	Ethyl alcohol.					
0	. .	. .	30	25.50	74.57	9.20	60	24.94	90	49.62	. .
1	. .	. .	31	27.18	73.14	9.76	61	25.50	91	50.87	100.00
2	. .	100.00	32	28.67	71.50	10.32	62	26.06	92	52.66	99.00
3	. .	99.33	33	30.33	70.00	10.87	63	26.60	93	54.00	98.00
4	. .	98.69	34	32.00	68.00	11.43	64	27.15	94	55.80	97.00
5	. .	98.06	35	33.50	66.00	11.99	65	27.71	95	57.60	96.00
6	. .	97.44	36	35.16	64.00	12.54	66	28.29	96	59.60	95.00
7	. .	96.80	37	37.00	62.00	13.10	67	28.88	97	61.75	94.00
8	. .	96.13	38	40.00	59.75	13.64	68	29.44	98	64.00	91.60
9	. .	95.42	39	43.93	. .	14.19	69	30.00	99	66.75	88.50
10	. .	94.71	40	. .	. .	14.73	70	30.71	100	70.00	85.50
11	. .	94.00	41	. .	. .	15.23	71	31.47	101	75.00	. .
12	. .	93.28	42	. .	. .	15.73	72	32.21	. .	. .	. .
13	. .	92.55	43	. .	. .	16.23	73	32.93	. .	. .	. .
14	. .	91.75	44	. .	. .	16.73	74	33.69	. .	. .	. .
15	1.34	90.92	0.33	45	. .	. .	17.23	75	34.43	. .	. .
16	3.00	90.08	1.00	46	. .	. .	17.73	76	35.09	. .	. .
17	4.64	89.25	1.62	47	. .	. .	18.23	77	35.99	. .	. .
18	6.34	88.45	2.25	48	. .	. .	18.73	78	37.00	. .	. .
19	8.00	87.64	2.93	49	. .	. .	19.23	79	37.90	. .	. .
20	9.67	86.73	3.56	50	. .	. .	19.73	80	38.82	. .	. .
21	11.34	85.80	4.19	51	. .	. .	20.25	81	39.64	. .	. .
22	13.00	84.80	4.82	52	. .	. .	20.77	82	40.64	. .	. .
23	14.67	83.60	5.39	53	. .	. .	21.29	83	41.64	. .	. .
24	16.17	82.40	5.94	54	. .	. .	21.81	84	42.75	. .	. .
25	17.72	81.20	6.50	55	. .	. .	22.33	85	43.75	. .	. .
26	19.33	80.00	7.06	56	. .	. .	22.85	86	44.75	. .	. .
27	20.93	78.75	7.58	57	. .	. .	23.38	87	46.00	. .	. .
28	22.47	77.43	8.09	58	. .	. .	23.90	88	47.25	. .	. .
29	23.96	76.00	8.64	59	. .	. .	24.43	89	48.38	. .	. .

The difference in refraction between the two alcohols varies considerably for different strengths. In the case of methyl alcohol, starting at zero (or water containing no alcohol), at which the reading on the immersion at 20° is 14.5, the refraction gradually increases with increasing strength of methyl alcohol up to about 50 per cent. of the latter by weight, where the refraction reaches its maximum, after which, for higher strengths of methyl alcohol, it drops quite rapidly, until at 100 per cent. the refraction is but 2.0.

In the case of ethyl alcohol, starting as before with pure water and increasing the strength of the solution in alcohol, the refraction increases quite rapidly up to solutions of about 75 per cent. strength, where it then drops slightly, but by no means to such an extent as in the case of methyl alcohol. It will thus be seen that by far the widest variations in refraction between the two alcohols take place above 50 per cent. in strength.

From the peculiar shape of both alcohol curves, rising gradually to a maximum and then falling, no confusion should be caused by the fact that in some cases one scale reading may correspond to two different percentages of strength of the same alcohol.

The detection of wood alcohol by this method is comparatively simple, and consists in submitting to refraction with the immersion refractometer the distillate which one makes for the determination of ethyl alcohol in the regular manner in alcoholic beverages, essences, tinctures, extracts, or whatever may be the nature of the substances to be examined. If the refraction of the liquid shows the percentage of alcohol agreeing with that obtained from the specific gravity in the regular manner, it may safely be assumed that no methyl alcohol is present. If, however, there is an appreciable amount of methyl alcohol, the low refractometer reading will at once indicate the fact. If the absence in the solution of other refractive substances than water and the alcohols is assured, this qualitative test by difference in refraction is conclusive; but if there is doubt, a confirmatory test by the Mulliken and Scudder method[1] should be made.

Thus not only can methyl alcohol readily be detected, but the amount may approximately, and in some cases very accurately, be determined. Addition of methyl to ethyl alcohol decreases the refraction in direct proportion to the amount present. Hence the quantitative calculation may readily be made by interpolation in Table II, which follows, using the figures for pure ethyl and methyl alcohol of the same alcoholic strength as the sample. The degree of accuracy of this calculation varies with the strength of alcohol. For instance, with an alcoholic strength of 10 per cent. there is less exactness than at 50 per cent. strength, where 1 per cent. or even less can readily be determined. From this point on the delicacy of the process naturally increases, until at 90 per cent. strength 0.1 per cent. of methyl alcohol may be determined with accuracy.

Table II shows the refraction on the immersion refractometer corresponding to each percentage of alcohol, both ethyl and methyl, by weight, all readings being taken at exactly 20° C. This table will show at a glance whether a solution of given strength of alcohol, as determined from the specific gravity, contains ethyl or methyl alcohol or is a mixture of the two.

[1] *Loc. cit. supra.*

TABLE II — Scale Readings on Zeiss Immersion Refractometer at 20° C. Corresponding to Each Per Cent. by Weight of Ethyl and Methyl Alcohols

Per cent. alcohol by weight.	Scale Readings.		Per cent. alcohol by weight.	Scale Readings.		Per cent. alcohol by weight.	Scale Readings.		Per cent. alcohol by weight.	Scale Readings.	
	Methyl alcohol.	Ethyl alcohol.		Methyl alcohol.	Ethyl alcohol.		Methyl alcohol.	Ethyl alcohol.		Methyl alcohol.	Ethyl alcohol.
0	14.5	14 5	30	32.8	69.0	60	37.9	96.2	90	16.1	98.6
1	14.8	16.0	31	33.5	70.4	61	37.5	96.7	91	14.9	98.3
2	15.4	17.6	32	34.1	71.7	62	37.0	97.1	92	13.7	97.8
3	16.0	19.1	33	34.7	73.1	63	36.5	97.5	93	12.4	97.2
4	16.6	20.7	34	35.2	74.4	64	36.0	98.0	94	11.0	96.4
5	17.2	22.3	35	35.8	75.8	65	35.5	98.3	95	9.6	95.7
6	17.8	24.1	36	36.3	76.9	66	35.0	98.7	96	8.2	94.9
7	18.4	25.9	37	36.8	78.0	67	34.5	99.1	97	6.7	94.0
8	19.0	27.8	38	37.3	79.1	68	34.0	99.4	98	5.1	93.0
9	19.6	29.6	39	37.7	80.2	69	33.5	99.7	99	3.5	92.0
10	20.2	31.4	40	38.1	81.3	70	33.0	100.0	100	2.0	91.0
11	20.8	33.2	41	38.4	82.3	71	32.3	100.2	. .	. .	. .
12	21.4	35.0	42	38.8	83.3	72	31.7	100.4	. .	. .	. .
13	22.0	36.9	43	39.2	84.2	73	31.1	100.6	. .	. .	. .
14	22.6	38.7	44	39 3	85.2	74	30.4	100.8	. .	. .	. .
15	23.2	40.5	45	39.4	86.2	75	29.7	101.0	. .	. .	. .
16	23.9	42.5	46	39.5	87.0	76	29.0	101.0	. .	. .	. .
17	24.5	44.5	47	39.6	87.8	77	28.3	100.9	. .	. .	. .
18	25.2	46.5	48	39.7	88.7	78	27.6	100.9	. .	. .	. .
19	25.8	48.5	49	39.8	89.5	79	26.8	100.8	. .	. .	. .
20	26.5	50.5	50	39.8	90.3	80	26.0	100.7	. .	. .	. .
21	27.1	52.4	51	39.7	91.1	81	25.1	100.6	. .	. .	. .
22	27.8	54.3	52	39.6	91.8	82	24.3	100.5	. .	. .	. .
23	28.4	56.3	53	39.6	92.4	83	23.6	100.4	. .	. .	. .
24	29.1	58.2	54	39.5	93.0	84	22.8	100.3	. .	. .	. .
25	29.7	60.1	55	39.4	93.6	85	21.8	100.1	. .	. .	. .
26	30.3	61.9	56	39.2	94.1	86	20.8	99.8	. .	. .	. .
27	30.9	63.7	57	39.0	94.7	87	19.7	99.5	. .	. .	. .
28	31.6	65.5	58	38.6	95.2	88	18.6	99.2	. .	. .	. .
29	32.2	67.2	59	38.3	95.7	89	17.3	98.9	. .	. .	. .

The fact should be borne in mind that in the examination of flavoring extracts it is difficult to separate out the volatile oils so completely as to prevent minute traces from appearing in the distillate. These, and indeed any volatile substance present in marked degree, appreciably affect the accuracy of the quantitative results, though mere traces do not cause serious error. The presence of notable amounts of acetone exercises also a marked effect, but the purified wood alcohol commonly used as an adulterant contains so little acetone that it may ordinarily be neglected in expressing approximate results. Pure acetone refracts considerably lower than ethyl alcohol.

Two or three examples of actual cases, as found in the routine inspection of foods and drugs in Massachusetts, will best illustrate

the method of calculation. For determination of total alcohol from the specific gravity, Hehner's alcohol tables were used.

(1) A lemon extract, found by the polariscope to contain 4.9 per cent. of lemon oil by volume and 90.20 per cent. of alcohol by volume at 15°, was freed from lemon oil by diluting four times with water, treating with magnesia in the regular manner, and filtering. A measured portion of the filtrate was then distilled, and the distillate made up to the measured portion taken. This distillate was found to have a specific gravity of 0.9736, corresponding to 18.38 per cent. alcohol by weight,[1] and to have a refraction of 35.8 on the Zeiss immersion refractometer.

By interpolation in Table II the readings of ethyl and methyl alcohol corresponding to 18.38 per cent. alcohol are 47.2 and 25.4, respectively, the difference being 21.8. $47.2 - 35.8 = 11.4$. $(11.4 \div 21.8)\ 100 = 52.3$. In this case 52.3 per cent. of the alcohol present was methyl.

(2) An orange extract was found with 1.5 per cent. of orange oil and 83.2 per cent. of alcohol by volume at 15° C. Specific gravity of the $\frac{1}{4}$-strength distillate, freed from oil as in the case of the lemon extract, was 0.9754, corresponding to 16.92 per cent. alcohol by weight. Refraction of the distillate at 20° C. was 42.0. Readings of ethyl and methyl alcohol of 16.9 strength are, according to Table II, 44.3 and 24.5, respectively. Difference, 19.8. $44.3 - 42 = 2.3$. $(2.3 \div 19.8)\ 100 = 1.2$. Thus 1.2 per cent. of the alcohol present was methyl.

(3) 6.3 c.c. of tincture of iodine, after titration with N/10 sodium thiosulphate (in the regular manner for determining its strength according to the United States Pharmacopœia), was neutralized with N/10 sodium hydroxide, and distilled, collecting 25.2 c.c. of the distillate, corresponding to a dilution of 1 : 4 of the sample. The distillate contained 20.92 per cent. alcohol by weight; refraction 27.5 at 20° C., indicating 99.0 per cent. of the alcohol to be methyl. There is no doubt that the alcohol in this case was entirely methyl, the slightly high refraction of the distillate being due to the presence of a slight amount of volatile substance formed by decomposition of the tincture of iodine.

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[1] Our methyl-ethyl alcohol tables being most conveniently worked out on the weight per cent. basis, the per cent. by weight rather than by volume of the dilute distillate is here taken. Percentage of total alcohol in the extract, as well as of lemon oil, we commonly express by volume. In this case the specific gravity, 0.9736, corresponds to 22.55 per cent. alcohol by volume. The per cent. by volume of total alcohol in the extract, 90.20 at 15° C., is found by multiplying 22.55 by 4 to correct for the dilution.

The accuracy of the method is shown in a general way by a series of experiments, the results of which are tabulated as follows: —

TABLE III — READINGS OF EXPERIMENTAL MIXTURES OF METHYL AND ETHYL ALCOHOLS

Sp. gr. 15° C.	Per cent. alcohol by weight.	Scale reading, 20° C.	Methyl Alcohol.		Ethyl Alcohol.	
			As prepared, per cent.	As found, per cent.	As prepared, per cent.	As found, per cent.
0.8190	91.36	33.9	68.52	69.88	22.84	21.48
0.8190	91.36	54.9	45.68	47.41	45.68	44.95
0.9239	47.41	51.9	35.56	35.42	11.85	11.99
0.8190	91.36	76.3	22.84	23.75	68.52	67.61
0.9326	43.43	62.4	21.71	21.38	21.71	22.05
0.9643	25.64	37.2	19.23	19.76	6.41	5.88
0.9207	48.86	77.5	12.21	11.77	36.65	37.09
0.9753	17.00	34.0	8.50	8.92	8.50	8.08
0.9666	23.92	50.2	5.98	6.48	17.94	17.44

Contribution from the Department of Food and Drug Inspection of the Massachusetts State Board of Health

CHEMICAL ANALYSES OF A FEW VARIETIES OF ROASTED COFFEE

By HERMANN C. LYTHGOE

At the last meeting of the Association of Official Agricultural Chemists the writer submitted methods for the analysis of tea and coffee, which were accepted as provisional and printed in Circular 20, Bureau of Chemistry, United States Department of Agriculture. It was decided to make analyses of coffee by these methods, and samples of unground roasted coffee were obtained from three Boston wholesale coffee dealers, who guaranteed the samples to be of the variety named. Samples of Java, Mocha, Santos, Rio, and Porto Rico were obtained from each dealer. These samples, together with some coffee adulterants and adulterated coffee, were analyzed by the methods submitted, and the analyses are reported in the table.

It is unnecessary to give all the methods, but a few of the more important ones are as follows:—

a. Alkalinity of the Ash

Weigh 10 grams of the coffee in a platinum dish and burn to an ash in a muffle; boil the ash with 100 c.c. of water for ten minutes; filter, and wash with water until free from alkali. To the filtrate add from a burette an excess of tenth normal hydrochloric acid, boil to expel the carbonic acid, and determine the excess of acid by titrating with tenth normal alkali, using phenolphthalein as an indicator; express results as cubic centimeters of tenth normal acid required to neutralize the ash of 1 gram of coffee and also 1 gram of coffee ash.

b. Soluble Phosphates

Make the final solution of *a* slightly acid with dilute hydrochloric acid, and evaporate to dryness; add 50 c.c. of boiling water, and titrate in the usual manner with uranium solution.[1]

c. Insoluble Phosphates

Dissolve the insoluble ash of *a* in dilute hydrochloric acid, evaporate to dryness, add ten drops of dilute hydrochloric acid to the residue, dissolve in 50 c.c. of boiling water, add 1 gram of sodium acetate, and titrate with uranium solution.

d. Cold Water Extract

Winton's Method. — Place 4 grams of the sample in a 200 c.c. flask; add water to the mark, and allow to macerate eight hours, with occasional shaking; let stand sixteen hours more without shaking, filter, evaporate 50 c.c. of the filtrate to dryness in a flat-bottomed dish, dry at 100°, and weigh.

e. Reducing Sugars

Treat 100 c.c. of the cold water extract obtained in *d* with 0.5 gram of lead acetate, shake until dissolved; add 1 gram of sodium sulphate, shake until dissolved; filter, and determine the reducing sugars in the filtrate. Calculate as dextrose.

f. Ten Per Cent. Extract

Method of McGill.[2] — Weigh into a tared flask the equivalent of 10 grams of the dried substance; add water until the contents of the flask weigh 110 grams; connect with a reflux condenser, and heat, beginning the boiling in from ten to fifteen minutes. Boil for one hour, cool fifteen minutes, weigh again, making up any loss by the addition of water; filter, and take the specific gravity of the filtrate at 15°.

According to McGill, a 10 per cent. extract of pure coffee has a specific gravity of 1.00986 at 15°, and under the same treatment

[1] Sutton's Volumetric Analysis, 8th ed., p. 313.

[2] Transactions of the Royal Society of Canada, 1887.

chicory gives an extract with a specific gravity of 1.02821. In mixtures of coffee and chicory the approximate percentage of chicory may be calculated by the following formula: —

$$\text{Per cent. of chicory} = 100 - \frac{(1.02821 - \text{sp. gr.})\ 100}{0.01835}.$$

The index of refraction of the above solution may be taken with the Zeiss immersion refractometer or with the Abbé refractometer.

A 10 per cent. coffee extract n_D 20° = 1.3377.
A 10 per cent. chicory extract n_D 20° = 1.3448.

Determinations of the solids, ash, sugar, nitrogen, etc., may be made on the 10 per cent. extract if desired.

Coffee Adulterants. — Coffee is adulterated by the admixture, and occasionally by the substitution, of roasted wheat, peas, beans, pea hulls, bread, crackers, chicory, and other sweet roots. The chemical methods of analysis are of use largely to supplement the microscopical examination and to arrive at approximately quantitative results. The following are the principal chemical constants characteristic of the adulterants: —

Roasted cereals, legumes, etc.: low alkalinity of ash, fiber, petroleum-ether extract, and nitrogen; high reducing sugars, starch, and phosphates.

Roasted sweet roots: low fat and fiber; high sand, chlorine, cold water extract, sp. gr. of 10 per cent. extract, and very high reducing sugars.

Leguminous hulls: low starch and fat; high fiber.

The variation in the chemical composition of different coffees is so slight, that it is impossible to pick out any particular variety by a chemical examination. From the analyses reported, it seems as if the Mocha coffees were characterized by a low refraction of the fat and by high reducing sugars, while the Rio coffees appear to differ from the others in having the soluble phosphates much greater than the insoluble phosphates, but as yet there have not been sufficient analyses made to claim these differences as conclusive.

Thanks are due to Arthur D. Smith for many of the crude-fiber and carbohydrate determinations.

TABLE

Analyses of Roasted Coffee

		Moisture.	Ash.	Water soluble ash.	Sand.	Chlorine.	Alkalinity of ash of 1 gram of substance c.c. $\frac{N}{10}$ acid.	Alkalinity of 1 gram of ash c.c. $\frac{N}{10}$ acid.	Soluble P_2O_5.	Insoluble P_2O_5.	Petroleum-ether extract.		Total nitrogen.	Cold water extract.	Alcohol extract.	Reducing sugars.	Starch by diastase.	Crude fiber.	Caffeine.	Ten Per Cent. Extract.				
																				Sp. gr. 15°.	Immersion refractometer reading 20°.	n_D 30°.	Solids.	Ash.
		%	%	%	%	%			%	%	%	n_D 30°	%	%	%	%	%	%	%				%	%
Santos	A	1.40	4.16	3.46	0.00	0.023	2 97	71.4	0.319	0.346	14.58	1.4754	2.26	20.80	16.83	0.52	2 28	13.41	1.25	1.0107	26.7	1.33770	2.64	0.40
	B	1.87	4.31	3 62	0.00	0.023	3.36	75.7	0.286	0.295	13.84	1.4754	2.26	22.72	17.11	0.68	1.00	11.02	1.10	1.0108	26.9	1.33777	2.64	0.39
	C	1.31	3.80	3.00	0.00	0.019	3.35	85.6	0.273	0.295	13.86	1.4750	2.39	21.70	17.80	0.75	2.32	14.71	1.20	1.0101	26.0	1.33743	2.46	0.30
Porto Rico	A	1.29	4.05	3.30	0.00	0.016	3.53	87.2	0.305	0.337	13.00	1.4752	2.28	22.48	15.70	0.50	2.17	13.11	1.38	1.0107	26.6	1.33766	2.60	0.37
	B	1.26	4.06	3.27	0.00	0.020	3.72	92.6	0.226	0.351	13.34	1.4750	2.26	21.76	16.36	0.63	1.58	12.93	1.21	1.0104	26.3	1.33754	2.50	0 36
	C	1.48	4.12	3.32	0.00	0.016	3.66	88.8	0.333	0.328	14.12	1.4760	2.33	24.44	16.91	0.54	2.62	12.50	1.32	1.0113	27.6	1.33804	2.77	0.30
Rio	A	1.76	4.06	3.40	0.00	0.020	4.16	102.3	0.213	0.166	13.38	1.4758	2.14	22.66	17.00	0.68	2.82	14.08	1.11	1.0103	25.5	1.33724	2.48	0.40
	B	2.34	3.91	3.24	0.00	0.021	3.17	81.2	0.356	0.227	13.71	1.4753	2.18	22.61	17.34	0.78	1.47	13.10	1.10	1.0101	25.8	1.33735	2.46	0.36
	C	2.10	3.74	3.06	0.00	0.023	3.22	86.6	0.363	0.236	13.53	1.4756	2.26	22.75	17.37	0.61	2.62	11.91	1.17	1.0101	26.0	1.33743	2.46	0.30
Mocha	A	2.05	4.05	3.25	0.00	0.016	3.94	97.4	0.282	0.351	14.84	1.4737[1]	2.28	24.00	18.01	1.78	2.30	11.22	1.16	1.0106	26.4	1.33758	2.65	0.40
	B	2.95	3.85	3.07	0.00	0.021	3.26	84.7	0.333	0.364	14.47	1.4743[1]	2.00	20.27	17.96	0.94	1.85	12.34	1.00	1.0101	26.3	1.33754	2.47	0.36
	C	2.40	3.80	3.00	0.00	0.012	3.54	93.3	0.337	0.545	15.18	1.4741[1]	2.02	24.18	19.55	1.42	2.90	13.20	1.18	1.0111	27.3	1.33793	2.72	0.40
Java	A	3.34	4.09	3.27	0.00	0.016	3.88	95.0	0.258	0.421	12.61	1.4752	2.48	23.85	15.95	0.32	2.95	13.43	1.34	1.0110	26.9	1.33777	2.63	0.39
	B	3.35	4.38	3.56	0.00	0.019	3.54	80.8	0.194	0.388	12.28	1.4758	2.35	22.19	15.45	0.42	2.32	13.77	1.30	1.0107	26.5	1.33762	2.58	0.38
	C	3.44	3.96	3.10	0.00	0.011	2.95	74.5	0.235	0.383	13.54	1.4752	2.56	23.20	16.21	0.66	3.34	14.75	1.27	1.0108	26.6	1.33766	2.62	0.38
Highest		3.44	4.38	3.62	0.00	0.023	4.16	102.3	0.424	0.545	15.18	1.4760	2.56	24.44	19.55	1.78	3 34	14.75	1.34	1.0113	27.6	1.33804	2.77	0.40
Lowest		1.29	3 74	3.00	0.00	0.011	2.95	71.4	0.194	0.166	12.28	1.4750	2.00	20.27	16.45	0.32	1.00	11.02	1.00	1.0101	26.0	1.33743	2.46	0.30
Average		2.16	4.03	3.26	0.00	0.018	3.55	87.1	0.285	0.329	13.75	1.4754	2.27	22.63	17.03	0.75	2.30	13.03	1.20	1.0105	26.6	1.33766	2.72	0.37

Analyses of Coffee Substitutes and of Adulterated Coffee

Roasted wheat	5.60	5.71	2.82	0.00	. .	0.34	6.0	0.649	1.460	2.40	. .	1.84	25.88	10.72	4.10	28.58	6.23	0.00	. .	. .	. .	. .	. .	. .
Roasted chicory	5.55	4.37	2.27	0.81	0.080	0.95	21.8	0.277	0.314	0.88	. .	1.10	72.92	34.39	19.34	2.10	5.91	0.00	1.0307	45.0	1.34463	7.44	0.26
Coffee and chicory	5.08	3.96	3.14	0.06	0.026	3.05	77.0	0.286	0.323	8.32	. .	1.89	31.79	21.66	5.06	2.21	14.31	0.95	1.0142	30.5	1.33915	3.62	0.29
Coffee, chicory, and pea hulls	3.64	4.97	4.05	0.24	0.284[2]	2.60	65.6	0.472	0.740	9.56	1.4745	2.17	25.00	14.25	3.00	3.78	17.87	1.00	. .	. .	. .	. .	. .	. .

[1] Omitted from average.

[2] Admixture of salt.

A REVISION OF THE COCCACEÆ[1]

By C.-E. A. WINSLOW and ANNE F. ROGERS

The classification of the bacteria presents peculiar difficulties, for several reasons. Morphological distinctions are so slight that physiological characters must necessarily be invoked in order to separate and classify the various organisms, and these physiological characters are often variable. Pathogenicity may be taken as a type of those powers of the organism which are easily and profoundly modified by external conditions. On the other hand, there are numerous characters which appear to be extremely constant. Such minute differences as occur in the resistance of different races to unfavorable conditions often remain unchanged through long periods of cultivation. In using these constant characters for classification we are met by another difficulty. Though constant, the differences are very minute, and in studying a number of organisms a perfect gradation is often found between the widest extremes. This is exactly what should be expected from organisms which reproduce only by asexual methods, since it is the fusion of independent cells which swamps minor differences, producing the uniformity of species among higher plants. With asexual reproduction every minute variation which is inheritable must persist unchanged until some other chance variation occurs. Each such variation means a new and different type of bacterium.

The immense number of generations which may succeed each other in a short space of time makes boundary lines as shifting as they would become among the higher plants if a dozen geological epochs were considered all at once.

Since, with unicellular organisms, acquired characters may probably be inherited in a higher degree than with other forms, existing races of bacteria will be markedly influenced by the selective effect of environmental conditions, and must bear the impress of their recent history.

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[1] Preliminary communication. From the Biological Laboratories of the Massachusetts Institute of Technology. Reprinted from *Science* N. S., April 28, 1905, XXI, No. 539, pp. 669-672.

There are, therefore, no species among the bacteria in quite the sense in which we ordinarily use the word — as indicating a group of individuals bound together by a number of constant characters and easily identified by mutual fertility. From one point of view each distinct race might be considered a species; but to apply a name for every grade of difference in each varying character would be impracticable, and such names could have no true specific value. The best solution of the difficulty is the establishment of certain types around which the individual organisms may be more or less closely grouped; but it must clearly be recognized that the groups thus formed are defined by relation to the type at their centre, and are not sharply marked off at their extremities from the other groups adjacent.

It is impossible to make a natural classification of the bacteria which shall be a true expression of phylogeny by considering a single character at a time — for example, by dividing a group dichotomously, first according to morphology, then according to liquefaction, etc. Larger groups, at least, should manifestly be indicated by the collocation of several characters, the association of any two of which markedly strengthens their significance. By applying this principle five fairly well-marked genera of Coccaceæ may be distinguished. Four of these, *Sarcina*, *Micrococcus*, *Streptococcus*, and *Ascococcus*, date back to the early days of bacteriology, although the latter term has fallen into disuse. The mere property of zoöglœa formation should not be considered of generic importance, but the few peculiar species which are capable of growing under purely saprophytic conditions and producing large gelatinous masses are so far marked off from other cocci as to warrant, in our judgment, the retention of Cohn's genus. The genera *Micrococcus*, *Streptococcus*, and *Sarcina* are retained, since in them morphological differences appear to be correlated with differences in biochemical characters or habitat, and we have considerably enlarged the definitions of these genera to include physiological and ecological factors. With regard to the genus *Diplococcus*, suggested by Weichselbaum for the parasite of pneumonia, it should be remembered that any coccus may at times occur in pairs. Yet those organisms which are strictly parasitic, and which normally occur only in aggregations of two cells, appear to mark a valid group. The morphological character of a genus must never be too rigidly interpreted. It refers to the typical and most commonly characteristic growth forms; and other groupings may at times occur. Therefore we recognize five

genera, based in each case on a more or less constant association of several independent characteristics. The old genera *Merispomedia* and *Staphylococcus* are merely synonyms of Cohn's *Micrococcus*, and *Ascococcus* antedates *Leuconostoc*. Fischer's characterization of *Pediococcus*, by regular division into two sections at right angles to each other, rests upon a variable and thoroughly artificial character, and probably includes some species of *Micrococcus* and some imperfectly studied species of *Sarcina*.

With regard to the genera *Planosarcina* and *Planococcus*, founded upon the single characteristic of the possession of flagella, there may be more uncertainty. The slow revolution and steady translation observed by Ali-Cohen and Migula as associated with flagella is certainly a phenomenon distinct from the irregular vibratory and rotary movements noted by other observers, but the resemblance between motile and non-motile forms is so close in all other characters that we cannot consider this single property to be of generic importance.

The five genera above mentioned have been discussed first because their characteristics are already somewhat familiar, but in logical order the larger subdivisions should have been previously considered.

The family Coccaceæ, although defined only by the spherical form of the individual, is a thoroughly satisfactory natural group, its members being also marked off in certain physiological characters from individuals of other groups. The family appears to be divisible into two subfamilies. The first, for which we suggest the name Paracoccaceæ (paratrophic cocci), includes *Diplococcus* and *Streptococcus*, parasitic forms which do not develop abundant growth on artificial media and which thrive better under anaërobic than under aërobic conditions, and appear in small cell aggregates of pairs or chains. The second subfamily, the Metacoccaceæ (metatrophic cocci), includes *Micrococcus*, *Sarcina*, and *Ascococcus*, saprophytic or semi-saprophytic types, which are aërobic and form abundant surface growths of large cell groups.

The species of the Coccaceæ are considerably more obscure. We have reviewed the descriptions of 445 supposedly distinct species given by Cohn, Migula, Flügge, Chester, Sternberg, Lehmann and Neumann, Engler and Prantl, Rabenhorst, Frankland, and Woodhead, and find a wonderful amount of duplication. Our observations have convinced us that minute differences in morphology, as, for example, the distinction between large and small cells or long and short chains, are not sufficiently constant for the erection of species. Again, slight

differences in the appearance of colonies on gelatin, which form a large number of German species, vary so markedly, according to the composition of the medium and conditions of incubation, that they may be disregarded. The turbidity and sediment in broth varies with the age of the culture; what is first turbidity later settles to form sediment, and those constant differences which do exist appear to be connected with the size of the cell aggregates. Organisms growing in large groups, like most of the sarcinæ, produce heavy sediment and often colony-like groups on the walls of the tube, while those in which the cells readily separate exhibit a more diffuse turbidity. The growths on potato and Nährstoff agar are correlated with the general vigor of a particular race, and vary markedly. Temperature relations are similarly inconstant, and what marked differences exist are correlated with other characters, to which we have given weight. For example, the streptococci, as a rule, thrive best at the body temperature, while the sarcinæ and many micrococci grow better or as well at 20°.

There remain, then, for the establishment of species the relation of the organism to gelatin, its action upon sugars, its pigment production, and its power to form nitrites and indol. In regard to all these points much more thorough study is needed. In particular, almost no data exist with regard to indol and nitrite production. By using the first three characters with one or two others which are of importance in special cases, we have made a tentative division of the 445 described forms under thirty-one types. A careful comparison of the published descriptions furnished no evidence for more true species, and eighty-five cultures, isolated from various sources and obtained from the principal American laboratories, which we have studied in considerable detail, fall naturally under some one of the types established. *S. erysipelatos* includes twenty of these cultures; *M. aureus*, eleven; *M. orbicularis*, eight; *M. ochraceus*, five; *M. ureæ*, three; *M. canescens*, five; *M. candicans* and *ventriculi*, two each; *M. luteus*, *M. cinnabareus*, *M. æthebius*, *S. subflava*, *S. incarnata*, and *S. aurantiaca*, one each. It is very probable that our further investigation will warrant the division of some of these types, but we present the thirty-one species below tentatively and subject to later revision. It must be understood, as noted above, that in all cases the names mark only types, numerous intermediate races existing between.

FAMILY COCCACEÆ

Vegetative cells spherical

SUBFAMILY 1. PARACOCCACEÆ (*New Subfamily*)

Parasites (thriving only, or best, on, or in, the animal body). Thrive well under anaërobic conditions. Many forms fail to grow on artificial media; none produce abundant surface growths. Planes of fission generally parallel, producing pairs, or short or long chains.

Genus 1. *Diplococcus* (Weichselbaum)

Strict parasites. Not growing or growing very poorly on artificial media. Cells normally in pairs surrounded by a capsule.

Under *Diplococcus* are three species, *D. pneumoniæ* Weich., *D. Weichselbaumii* Trev., and *D. gonorrhœæ* Neisser, distinguished by the tissue of the host affected, and by the peculiar morphology and staining reactions of the latter species.

Genus 2. *Streptococcus* (Billroth).

Parasites (see above). Cells normally in short or long chains (under unfavorable cultural conditions, sometimes in pairs and small groups, never in large groups or packets). On agar streak effused translucent growth, often with isolated colonies. In stab culture, little surface growth. Sugars fermented with formation of acid.

Under *Streptococcus* we find the vast majority of organisms indistinguishable from *S. erysipelatos* Fehleisen. Two varieties may perhaps be recognized, var. *involutus* Kurth, and var. *tenuis* (new variety), which fails to coagulate milk. Representatives of another species, *S. enteritidis* Escherich, which liquefies gelatin, are occasionally found.

SUBFAMILY 2. METACOCCACEÆ (*New Subfamily*)

Facultative parasites or saprophytes. Thrive best under aërobic conditions. Grow well on artificial media, producing abundant surface growths. Planes of fission often at right angles; cells aggregated in groups, packets, or zoöglœa masses.

Genus 3. *Micrococcus* (Hallier) Cohn.

Facultative parasites or saprophytes. Cells in plates or irregular masses (never in long chains or packets). Acid production variable.

Under this genus thirteen species may be distinguished by the three properties of liquefaction, acid production, and chromogenesis, their characters being indicated in tabular form below.

GELATIN LIQUEFIED

	ACID	NON-ACID
Yellow	*M. aureus* (Ros.) Mig.	*M. orbicularis* Ravenel.
White	*M. pyogenes* (Ros.) Mig.	*M. rhenanus* Mig.
Red	*M. roseus* Flügge.	*M. fulvus* Cohn.

GELATIN NOT LIQUEFIED

	ACID	NON-ACID
Yellow	*M. luteus* (Schroter) Cohn.	*M. ochraceus* Rosenthal.
White	*M. candicans* Flügge.	*M. canescens* Mig.
Red		*M. cinnabareus* Flügge.

M. ureæ Cohn. Ammoniacal fermentation of urine produced. Gelatin not liquefied.
M. æthebius Trevisan. Ammoniacal fermentation of urine produced. Gelatin liquefied.

Genus 4. *Sarcina* (Goodsir).

Saprophytes or facultative parasites. Division under favorable conditions in three planes, producing regular packets. Sugars as a rule not fermented.

Under *Sarcina* are eleven species, eight of which are grouped as follows: —

	GELATIN LIQUEFIED	GELATIN NOT LIQUEFIED
Yellow	*S. subflava* Ravenel.	*S. ventriculi* Goodsir.
White	*S. candida* Lindner.	*S. pulmonum* Virchow.
Red	*S. rosacea* Lindner.	*S. incarnata* Gruber
Brown	*S. cervina* Stub.	*S. fusca* Gruber.

In addition three somewhat aberrant species must be recognized — *S. aurantiaca* Flügge, a yellow liquefying chromogen, which unlike the other members of the group has the power to coagulate milk, with *S. agilis* (Ali-Cohen) Mig. and *S. tetragenus* (Mendoza) Mig., respectively red and yellowish-white motile forms. From study of the literature and a few cultures of supposedly motile forms we are inclined to believe that all the truly motile cocci may be classed under these two heads.

Genus 5. *Ascococcus* (Cohn).

Generally saprophytic. Cells imbedded in large irregularly lobed masses of zoöglœa, in presence of carbohydrates. Acid usually formed.

Two species are distinguished, *A. mesenteroides* Cienkowski, a non-liquefying form, and *A. mucilaginosus* Migula, a liquefier.

The characters of the species tentatively defined above are still somewhat artificial, and may be subject to revision and modification when our studies are complete. It is probable that the liquefaction of gelatin cannot bear any very direct relation to phylogeny, since in every genus except *Diplococcus*, and in each subdivision of a genus, a liquefying and a non-liquefying form occur parallel to each other.

Synonymy will be discussed in our full communication later; but we have strictly followed the rules of priority as recognized in other fields of systematic biology.

In reviewing our genera a serial arrangement is at once apparent. *Diplococcus* is strictly parasitic and commonly produces only aggregates of two cells. *Streptococcus*, also normally parasitic, thrives better, though still not luxuriantly, on artificial media, and its typical growth form is a chain. *Micrococcus* includes both pathogenic and non-pathogenic forms, but all grow abundantly on gelatin and agar in rather large irregular cell aggregates, while some produce acid and some alkalies in milk. *Sarcina* shows further development in the same direction, its growth form being larger and produced by three planes of division, its saprophytic habit being more marked (no truly pathogenic forms known to exist), with the power of acid production generally wanting. *Ascococcus*, in spite of its slight acid production and chain formation, appears on the whole to form the extreme of this series, since its entirely saprophytic existence and large vegetative growth forms are far removed from the pathogenic micrococci. The genera above defined seem to mark the important transition stages, beginning with such strict parasites as *D. Weichselbaumii*, and ranging through the intermediate forms of streptococci, micrococci, and sarcinæ to the saprophytic *Ascococcus mesenteroides* at another extreme. We believe that these genera have true phylogenetic significance, and represent real groups of organisms having natural affinities.

THE EFFICIENCY OF COMMERCIAL PASTEURIZATION AND ITS RELATION TO THE MILK PROBLEM

By SAMUEL C. PRESCOTT

THE necessity for pure milk supplies for large cities has in recent years come to be recognized by sanitarians as of very great importance. Questions of water supply and sewage disposal have, in general, been successfully solved in the larger and older cities, but the milk problem has increased in complexity and seriousness as the cities and urban communities have grown in population, and thickly settled suburbs have encroached upon the regions formerly devoted to agricultural pursuits. Like water, milk is almost universally used as a source of food, especially for young children, as it is a natural food, and one high in food value. In each case the questions of quantity and quality have to be met. The problem of milk supply is, however, differentiated from that of water supply with respect to the source and the method of transportation. The water for a city is, in general, derived from a single large source, or few sources, in areas which may be so safeguarded as to prevent pollution with pathogenic or intestinal bacteria, and its transportation to the consumer is not attended by serious danger of infection. Milk, on the other hand, is obtained from a large number of small sources — the individual farms; it is constantly subject to contamination because of the methods of handling from the time it is drawn from the cow until it reaches the consumer. Furthermore, as milk is an organic material of the highest food value for microbic life, and especially an ideal food for those bacteria which can cause lactic fermentation and putrefactive changes, and which readily find their way into the milk unless great care is taken to prevent them, the possibility of an enormous development of bacteria in it is a matter of very great importance. Thus, paradoxically, the fact that milk is of high food value becomes a source of weakness when we consider it from the industrial bacteriological standpoint.

The real milk problem which we have to consider is not how a sufficient quantity of milk with a definite percentage of fats and solids

may be obtained, but how the inhabitants of the cities shall be provided with milk which is sweet, clean, free from questionable substances, and low in bacteria. Normal milk when drawn under aseptic conditions from the udder of a healthy cow may contain a few bacteria, or it may be entirely sterile. Ordinary milk, on the other hand, is almost certain to contain large numbers of bacteria of widely varying types. Of these, some may be classed as harmless or relatively inactive, but the number thus behaving in a food substance like milk is comparatively small. The second class is the group of organisms derived largely from the hay of the stable or getting in from the air or from dust, and these are organisms which may not be disease-producing in the specific sense, but are undesirable in milk used for food for children, because they bring about more or less rapid fermentation with products which may or may not be harmful. Most important, however, are the organisms which may be classed as the acid-producing and the putrefactive bacteria, and which are very abundant in carelessly drawn milk. These, although apparently gaining entrance from the skin and hair of the cow and from other external sources, are really derived very largely from the intestinal tract, and drop into the pail in large numbers during the process of milking, unless special care is taken to keep the body of the cow in a clean condition. These are the organisms which bring about a rapid fermentation of the sugar of milk to lactic acid, and which, acting on the albuminoids, ultimately produce "rotten" milk. Because of the secondary changes which take place upon the proteid we may have developed in the milk chemical substances, products of putrefactive decomposition, which are unwholesome and may give rise to severe intestinal disorders.

It is also possible that there may be specific pathogenic organisms occurring in milk, as is well shown by the large number of epidemic outbreaks which have been due directly to infected milk. Swithinbank and Newman have pointed out that up to 1901 there have been no less than 330 such epidemics which have been traced to milk, and there are unquestionably many more where the responsibility has not been fixed. Of these, 195 were epidemics of typhoid fever, ninety-nine of scarlet fever, and thirty-six of diphtheria.

In view of what has already been said, it is easy to see what might be the sources of these organisms. The organisms of the first three groups may come from the air, from the food of the cattle, from the body of the cow, from the clothing and hands of the milker, or from

unclean utensils. The organisms of the last mentioned class come essentially from one source only, namely, from infected persons who have handled the milk at some period in its transfer from the cow to the consumer, and have transmitted the germs from their own bodies or clothing to this medium.

By the time the milk ordinarily produced has reached the city for delivery to its consumers, the number of bacteria has enormously increased. Bacteriological investigation has shown the number of bacteria per cubic centimeter in the milk of various cities to vary all the way from a few thousands to many millions, so that it is very difficult to give average results which are at all satisfactory. The greatest variations are found even in the milk of a single city, according to the source and age of the milk. Thus in New York, Park found the number of bacteria varying from 52,000 to 25,000,000 in milk brought to the city by the Harlem Railroad. Ordinary Boston milk has been found by the writer to vary from 10,000 to 39,000,000. St. Petersburg milk was shown by Zakherbekoff to vary from 450,000 to 1,153,600,000 bacteria per cubic centimeter, and the milk from many cities frequently contains from 5,000,000 to 100,000,000 germs. Such milk cannot be regarded as fresh or pure, and it is to guard against this condition that the activity of health boards and sanitarians is directed.

To this end the city of Boston has passed an ordinance that no milk shall be sold which contains more than 500,000 bacteria, or which has a temperature above 50° F. when it reaches the city. How many bacteria it may contain when it reaches the consumer is a point which would be well worth considering.

It may be asked how the conditions which have been implied may be improved. It is evident that they should be improved, and it is furthermore evident to the minds of those who have studied this question that they can be improved. Two lines naturally present themselves: first, the passing of ordinances or laws requiring much stricter observance of precautions in the production and handling of the milk; or second, the treatment of the milk in some way so as to destroy the bacteria. By the first of these methods the milk might be clean only from the bacteriological standpoint. Clean milk is a demonstrable possibility. There are numerous dairies scattered throughout the country, milk from which is shown by bacteriological examination to contain at most but a few hundred bacteria and to be free from "dirt" and other foreign matter. In order to obtain such milk the strictest cleanliness must be observed

in the stable, in the milkhouse, and everywhere wherever the milk is handled. Careful, intelligent supervision is what is necessary in order to provide clean milk, and this is the goal toward which the work of the sanitarian should be directed. (See "Clean Milk," by Dr. Belcher.)

The second method of producing milk low in bacteria is by pasteurization. Pasteurization consists essentially in the heating of the milk to such a temperature that a very large percentage of the organisms in it are destroyed. Pasteurization differs from sterilization in that the heat applied may be very much less, and consequently the change brought about, especially in the proteid, may be very much less marked; and, in the second place, because in pasteurized milk there are still some germs left alive, while in sterilization all living things are destroyed. When experiments are carried out on a small scale — what we may call theoretical pasteurization — a surprisingly high efficiency is often obtained when we consider the number of bacteria destroyed. When, however, pasteurization is carried out practically, as is done by the use of large pasteurizing machines, the percentage of bacteria destroyed is generally not quite as high. In theoretical pasteurization the milk is heated for a period of fifteen or more minutes at a temperature of 157° F. to 170° F. Pasteurization, *as practiced commercially*, consists generally in the heating of milk to a temperature of 160° F. to 165° F., and for a period varying from three-fourths of a minute to one and one-half to two minutes. If pasteurization is carried on below 165° F., very slight chemical change is brought about in the components of the milk. Above 165° the milk is slightly changed, so that the fat globules do not rise as readily and the milk does not show as well-marked a "cream line." The process of pasteurization has been developed until at the present time it is conducted on a very extensive scale, for it seems to be the easiest available present means of reducing bacteria to the number normal for pure milk. Probably about one-fifth of the milk sold in Boston has been treated in this way.

It is the purpose of this article to show the comparative efficiency of some commercial pasteurizers at present employed. Of these machines there are two or three types, all, however, similar in one respect, namely, that the milk comes in contact with a cylinder heated by steam, and is quickly raised to the pasteurizing temperature, 155° to 165° F. Some of these machines will pasteurize as much as 6,000 pounds per hour. When these machines are run under the most favorable conditions, there should be a reduction of from 97 to 99 per cent.

of the number of bacteria. This, however, is not always obtained in practice, because the conditions are not always maintained for the highest efficiency. The results, so far as the destruction of bacteria is concerned, are dependent upon two factors — temperature and time. Given the same time and the same temperature, practically the same bactericidal efficiency should be obtained with all the machines, regardless of their type. In the tables which follow, the results which have been obtained in the practical examination of commercial pasteurizers are given, and here it will be seen that the efficiency varies in general as the temperature, the higher the temperature the greater the percentage of bacteria destroyed.

TABLE I — Effect of Varying Temperature and Media

Machine No. 1

	Date.	Pasteurizing temperature. Degrees F.	Temperature after pasteurizing.	Raw Milk. Average Number of Bacteria per c.c.		Pasteurized Milk. Average Number of Bacteria per c.c.	
				Lactose agar.	Agar.	Lactose agar.	Agar.
1	February 13	156	55°	313,500	505,000	61,000	87,650
2	February 13	136	50°	323,200	343,800	50,000	37,300
3	February 13	158	. .	262,500	345,000	36,000	24,250
4	February 25	125	. .	130,000	260,000	2,670,000	2,900,000
5	February 25	155	48°	. .	1,450,000	176,000	202,500
6	March 9	146	. .	2,230,000	1,850,000	41,300	22,000
7	March 12	146-150	. .	190,000	245,000	8,250	9,000
8	March 12	155	. .	275,000	600,000	3,950	4,850
9	March 26	125	. .	2,470,000	1,010,000	1,025,000	568,000
10	March 26	140	. .	2,610,000	1,060,000	120,000	80,000
11	March 26	152	. .	2,360,000	740,000	55,000	65,000
12	April 16	132	. .	200,000	290,000	66,000	40,000
13	April 16	136-145	. .	. .	. .	45,000	21,000
. .	. .	Mixed	. .	. .	. .	. .	. .
14	April 16	145	. .	. .	. .	25,500	12,600
15	May 6	152	. .	1,430,000	1,500,000	75,000	41,000
16	May 6	152	. .	. .	. .	70,000	51,000
17	May 6	152	. .	. .	. .	57,500	38,000
18	May 6	154	. .	700,000	1,010,000	65,000	50,000
19	May 6	154	. .	. .	. .	60,000	50,000

In this table the effect of pasteurization has been determined using two kinds of culture media. While these differ in the number of bacteria actually developing, the efficiency of pasteurization is shown to be about the same with each.

TABLE II

MACHINE NO. 3

	Date.	Pasteurizing temperature. Degrees F.	Temperature after pasteurizing.	RAW MILK. AVERAGE NUMBER OF BACTERIA PER C.C.		PASTEURIZED MILK. AVERAGE NUMBER OF BACTERIA PER C.C.	
				Lactose agar.	Agar.	Lactose agar.	Agar.
A	February 18	155	. .	220,000	40,000	59,000	17,500
B	February 18	162	45°	410,000	135,000	66,000	15,000
C	February 18	160	45°	130,000	45,000	76,000	9,000
D	February 18	159	45°	3,170,000	1,265,000	120,000	86,000
E	February 27	161	43–44°	110,000	156,000	21,200	21,100
F	February 27	158	45–48°	180,000	206,000	9,800	10,000
G	February 27	152–157	. .	198,000	194,500	18,900	17,750
H	March 3	158–162	45°	600,000	825,000	. .	15,000
I	March 3	157–162	45°	1,000,000	370,000	5,500	10,850
J	March 12	140	. .	. .	. .	85,900	30,000
K	March 12	160	46°	140,000	60,000	12,900	11,500
L	March 31	155	. .	180,000	200,000	53,000	61,250
M	March 31	159	. .	150,000	140,000	36,750	37,850
N	March 31	164	. .	75,000	130,000	31,250	38,300
O	April 18	156	. .	. .	80,000	32,600	18,650
P	April 18	161	. .	. .	. .	17,500	14,300
Q	April 18	161	. .	. .	. .	21,400	19,800
R	April 18	161	. .	60,000	70,000	16,950	11,900
S	May 5	152	42°	60,000	100,000	2,800	1,800
T	May 5	150	43°	50,000	280,000	2,150	2,700
U	May 5	154	43°	. .	. .	2,100	1,200
V	. .	156	46°	. .	. .	3,800	1,600

Here the same general result is reached as in Table I.

TABLE III — EFFICIENCY OF COMMERCIAL PASTEURIZATION

(Machines run under practically constant temperature)

MACHINE NO. 1

(Capacity (approximate) 5,000 pounds per hour)

Test No.	Bacteria per c.c. in raw milk.	Temperature of machine.	Bacteria per c.c. in pasteurized milk.	Temperature of pasteurized milk.
1	2,235,000	166.0	7,400	42.0
2	1,750,000	164.0	14,750	43.0
3	1,010,000	164.0	12,000	40.0
4	2,220,000	163.0	17,500	40.0
5	1,440,000	162.5	17,600	41.0
6	1,240,000	163.0	13,200	40.0
7	930,000	162.5	15,300	40.5
8	630,000	162.5	22,600	41.0
9	1,465,000	163.5	10,000	41.5
10	1,410,000	163.5	8,900	42.0
11	1,190,000	163.5	19,500	39.0
12	1,375,000	163.5	16,000	39.5
13	2,570,000	163.5	14,650	40.0
14	2,590,000	163.5	12,100	40.0
15	2,160,000	163.5	20,800	40.5
16	2,440,000	163.5	1,500	Not recorded
17	1,620,000	. .	. .	. .
18	1,980,000	164.0	3,200	40.5
. .	Taken from the tank directly			. .
19	1,495,000	163.5	7,500	41.0
20	1,030,000	164.0	5,400	42.0
21	1,145,000	165.0	3,000	42.0
22	790,000	From tank directly	. .	. .
23	990,000	163.0	7,350	41.0
24	695,000	166.0	2,400	40.5
25	860,000	166.5	15,000	39.5
26	550,000	164.0	12,900	44.0
27	475,000	163.0	15,300	42.5
28	415,000	163.0	13,500	44.0
29	450,000	165.0	12,300	44.0
30	Overgrown	164.0	29,000	42.0
31	690,000	162.5	13,400	45.0
32	310,000	163.0	26,800	42.0

In this series an average percentage efficiency of 97.1 per cent. was obtained, *i. e.*, 97.1 per cent. of the bacteria were killed by exposure to a temperature approximating 164° F.

TABLE IV—EFFICIENCY OF COMMERCIAL PASTEURIZATION

(Machine run under practically constant temperature)

MACHINE NO. 2

(Capacity 6,000 pounds per hour)

Test No.	Bacteria in raw milk.	Temperature of machine.	Bacteria in pasteurized milk.	Temperature of pasteurized milk.
1	2,620,000	164.5	28,500	41.0
2	7,625,000	163.0	16,700	41.5
3	2,160,000	166.0	Overgrown	40.0
4	2,440,000	165.0	20,700	41.0
5	1,620,000	. .	. .	. .
6	1,980,000	164.0	7,100	41.0
. .	Taken from the tank directly			. .
7	1,495,000	164.0	19,200	42.0
8	1,030,000	164.0	33,600	43.0
9	1,145,000	165.0	13,800	43.0
10	790,000 From tank directly		. .	. .
11	990,000	163.0	19,400	43.0
12	695,000	168.0	18,000	43.0
13	900,000	165.0	3,700	43.0
. .	Tank sample		. .	. .
14	345,000	164.0	7,800	38.0
15	570,000	165.0	17,400	41.0
16	830,000	163.0	24,700	42.0
17	570,000	166.0	37,200	42.0
18	490,000	164.0	47,500	43.0
19	530,000	165.0	36,200	42.0
20	850,000	164.0	16,200	42.0
21	380,000	163.0	29,400	43.0
22	480,000	165.0	5,650	. .
23	440,000	167.0	10,800	43.0
24	740,000	163.0	39,200	43.0
25	600,000	167.0	15,600	44.0
26	850,000	163.0	23,000	43.0
27	560,000	164.0	10,000	44.0
28	Overgrown	164.0	17,700	44.0
29	460,000	163.0	11,100	42.5
30	985,000	162.0	11,000	43.0
31	855,000	160.0	55,900	42.0
32	410,000	162.0	29,500	42.0
33	680,000	166.0	35,200	42.0
34	710,000	160.0	17,000	42.0

Average efficiency, 96.1 per cent.

In the preceding tables the milks which have been subjected to examination may be regarded as representative of the ordinary milk delivered to the consumer in a large city. With milk which has been kept for some time, so that the number of bacteria is markedly above the average, pasteurization may show an exceedingly high efficiency, as is shown in the following table.

TABLE V — EFFECT OF PASTEURIZATION ON MILK HIGH IN BACTERIA

Sample No.	Raw milk. Bacteria per c.c.	Pasteurized milk. Bacteria per c.c.	Reduction, per cent.
1	7,600,000	86,000	98.9
2	9,700,000	31,000	99.7
3	6,100,000	29,000	99.5
4	7,350,000	34,000	99.5
5	6,200,000	98,000	98.4
6	5,100,000	88,200	98.3
7	6,150,000	48,300	99.2
8	6,405,000	64,750	99.0
9	3,675,000	60,200	98.4
10	3,250,000	29,900	99.1
Average	6,153,000	55,090	99.1

The results here numerically expressed may be explained perhaps by the fact that in this case the bacteria are probably all in a vegetative or rapidly multiplying condition, and hence are more readily affected by heat than when some of them are in the quiescent, or spore, state. It is possible that the small amount of free acid (lactic acid) which has been developed in the fermenting milk would be of material aid when combined with the effect of heat in destroying the bacteria.

While such a product may conform to the legal requirements as regards temperature and number of bacteria, it cannot be regarded as equal in food value to a fresh, sweet milk, either raw or in a pasteurized condition. It is the writer's belief that all pasteurized milk which is sold should be distinctly designated, so that the consumer may know whether he is buying fresh, untreated milk or milk which has been subjected to the heating process. Milk which has been pasteurized and is then sold as fresh milk is clearly a sophisticated product, even though it may be more wholesome than the untreated article. Furthermore, the ease with which the number of bacteria may be brought within the legal

limit renders it possible for unscrupulous dealers to utilize filthy, half decomposed milk high in bacteria, and by this simple process destroy the bacteria so that the milk may be sold as clean milk conforming with the legal requirements. To what extent harmful products (toxins) have been developed in the milk previous to its pasteurization and left unchanged by this process is unknown, but it might well be that such poisonous bodies could be present in considerable amount. It seems to the writer that not only should the pasteurized milk be so labeled, but there should also be a law limiting the age, acidity, and number of bacteria in milk which is to be pasteurized and subsequently exposed to sale.

While, therefore, the process of pasteurization may be very successfully carried out from the sanitary and hygienic point of view, it should be regarded as a means to an end. It goes without question that the major portion of pasteurized milk now sold is better than ordinary raw milk, yet the fact should not be lost sight of that a pure, clean supply of natural milk is the most to be desired.

Biological Laboratories,
September, 1905.

THE SEA-GOING BATTLESHIP[1]

By COMMANDER WILLIAM HOVGAARD, Royal Danish Navy

Introductory

The present paper is an attempt, on the basis of general principles, to arrive at the type and size of warship best suited to secure command of the ocean.

First, the fundamental elements of the design — armament, speed, and radius of action — are shown to depend on the work which the ship has to do, a work that varies from year to year with technical progress, political and strategical conditions, etc. These elements being chosen, it is shown how the other elements — nautical qualities and protection — follow from these and from conditions on the ocean as a logical consequence of the aforesaid general principles. The result does not indeed differ greatly from recent battleship designs, although important modifications are proposed; but, whatever the conclusion, it is believed that such a discussion must always be of interest, since it aims at basing the design on fundamental and unchangeable principles, instead of on current practice or personal views.

It appears that only by placing the design on such basis is it possible to avoid the vacillations in shipbuilding policy under which many navies have suffered, and only on such basis is it possible without error to discern the true direction which progress must follow under the present rapid development.

It is imperative, just at the present time, that we should carefully consider this question of the best type of battleship, for not only have the means of attack lately been considerably improved, but recent war experience has thrown light on their use, which with many people has shaken the faith in the existing type.

The improvements referred to in the means of attack are: —

1. Increased penetrative power of guns, due to higher velocity and

[1] Reprinted from the Transactions of the Society of Naval Architects and Marine Engineers, 1904, 12, pp. 73–100. Copyrighted by the Society.

improvement in the metal of projectiles, and to the use of caps. Thus the 12-inch gun has gained about 25 per cent. in penetrative power since 1901.

2. Advance in gunnery.

3. Development of the submarine boat and the torpedo.

The Russo-Japanese War has brought out the fact that submarine attack both by mines and torpedoes has been far *more frequently successful* than anticipated, although it cannot be asserted that the *effects* of such attack have exceeded what might have been expected.

Hence it has been argued that it is unreasonable to construct ships representing a capital of some eight million of dollars, which it takes several years to build and which carry a crew largely made up of trained experts, representing years of costly education, if such ships are quite frequently exposed to almost instantaneous destruction.

Notably the armor appears to many of little value, since it is useless in case of submarine attack, and since it is unable to keep out the projectiles of modern guns. Their conclusion is that it would be better to abandon or reduce the armor protection and build vessels of small or moderate displacement, since thereby the loss of the individual ship would be of less consequence, and the greater number of units would reduce the chances of loss for each ship. This idea was embodied in the principles of *la jeune école* in France already in the eighties,[1] and has recently been advocated by so eminent an authority as the late Vice-Admiral Makaroff.[2]

As shown in the following, such revolutionary policy of ship construction is likely to prove fatal to any power for whom command of the ocean is under certain contingencies of war a necessity.

It is shown that for service on the ocean the largest class of battleship offers the best combination of military and nautical qualities, and that hence, for a given expenditure, the greatest fighting value is obtained with this type. Smaller ships of whatever class, necessarily deficient in some or all of the essential qualities, will be unable to drive the large ships from the sea.

It is admitted that for coast work the large battleship is less suited now than formerly, although, as shown in this paper, its power to resist submarine attack may be greatly improved. It seems advisable

[1] Gabriel Charmes, La Réforme de la Marine.

[2] Paper read by Vice-Admiral Makaroff before the Naval Society of Kronstadt, March, 1903, Armored or Unarmored Vessels.

to entrust the coast defence and attack chiefly to smaller ships of special types, and to use the sea-going battleships for this service only in case of urgent necessity and then only with greatest caution. This implies virtually a restriction in the sphere of action, and hence in the importance of battleships, but there is still a long step to the abandonment of the type.

The sea-going battleships constitute the principal fighting strength on the sea; they form the nucleus of naval power, and to them all other types of sea-going warships are subsidiary, serving chiefly for their assistance and protection. The type that is to fulfill this function must be essentially a fighting ship, and should be able to engage all classes of vessels without ever being placed at a disadvantage. It should be able under certain circumstances to fight forts and shore batteries.

It should be capable of use both for offensive and defensive duties, and must generally be designed to operate all over the world. It should, therefore, have sufficient sea-going capability for continued ocean service and possess a great steaming radius. The speed must be such as not to place it at a disadvantage compared with battleships of other navies, nor should it fall below the speed of battleships of the same navy.

Without yet assigning quantitative values to the elements which make up the fighting capacity, we may state as a first general principle that the all-round use to which this class of vessel is to be put renders it *necessary to fulfill each of the claims to seaworthiness, armament, protection, speed, and endurance in a harmonious way*, so that no one of these elements shall be unduly favored at the expense of the others.

If a sea-going battleship is deficient in any one of these important qualities, even although she may excel in one or more of the others, she is liable, at one time or other, to be placed at a serious disadvantage, namely, when matched against an opponent in which these nautical and military qualities are more harmoniously balanced, even if the opponent is not of greater displacement.

This principle has always been followed in all successful battleship designs, but the repeated advocacy of smaller specialized types implies a doubt of its validity, which makes it necessary to further explain and prove the principle by showing that the various elements of a design are organically connected.

Another important principle follows from the all-round duties of the battleship, namely, that *the design should in every respect be based on*

"*probable average conditions*" and not on exceptional contingencies. This principle is indeed likewise generally conformed to, consciously or unconsciously. The difficulty in applying it lies in determining what may be fairly considered average conditions; but since a logical design seems impossible without such basis, it is necessary to make an estimate of them, a point which has received careful consideration in the following.

It may at first sight appear that principles and propositions are stated in this paper which are mere truisms, not worthy of statement and still less of proof or discussion. Consideration will show, however, that past history affords examples of the violation of even the most fundamental of such principles, and, moreover, that if we are to form a comprehensive conception of a problem so intricate as the design of a battleship it is necessary that all arguments bearing on the solution should be stated and the proper weight assigned to them.

1. Armament

The armament is the *raison d'être* of the battleship, which may in a sense be regarded as a floating, movable platform for carrying the armament, for transporting it to the place of action, and for bringing it into position. We must, therefore, first of all inquire into what the principal armament should be — guns or torpedoes?

Gun versus Torpedo. — The value of these weapons may be measured as the product of two factors: the probable frequency of successful application and their effects on the attacked structure. Neither of these admits of exact evaluation, and our conclusion must, therefore, be based on general considerations.

Bearing in mind that we deal here chiefly with fighting in the open sea and ships under way, it may be asserted that *the frequency of hits* with guns must far exceed that obtainable with torpedoes. This is due to the fact that an artillery fight can be carried on continuously for a great length of time and at considerable ranges; the torpedo can be used only intermittently and at short or moderate distances. Also the accuracy of the torpedo against a moving target falls far behind that of the gun. Recent progress in torpedoes has fully been matched by progress in the guns. In the Russo-Japanese War torpedoes have been used with great success against ships at anchor, but it has also been demonstrated that by proper precautions and vigilance it is possible to

ward off such attack. Against ships under way the torpedo has generally, if not always, proved unsuccessful. (In the battle off Port Arthur, August 10, 1904, about sixty torpedoes are said to have been fired, all without result.)

Turning to *the effects*, it must, on the other hand, be admitted that the effects of *torpedo explosions* are, in general, very serious. This is due not only to the magnitude of the damage, which is hardly greater than that of heavy shell exploding inside the ship, but chiefly to the circumstance that the explosion takes place under water, generally at some 10 feet below the surface, whereby the fundamental qualities of the ship — the buoyancy and the stability — are endangered, and frequently also the vitals are exposed to disablement.

An 18-inch torpedo, carrying a charge of about 220 pounds of gun cotton, will probably blow a hole in the side of a ship of at least 12 feet diameter. How far the damage will extend inwards depends largely on the nature of the obstructions opposed to the expansion of the gases, but it seems likely that as ships are now generally constructed the direct effects will extend some 12 to 18 feet inside the outer shell.[1]

These effects render the torpedo almost absolutely destructive against smaller vessels; but large battleships, as now ordinarily constructed, will in most cases stand a blow from a torpedo without more than temporary disablement, capable of repair. This has been shown on several occasions at Port Arthur. We may, however, as shown hereafter, without great sacrifices construct large ships in such a way that a single torpedo shall not, in general, put them out of action, and so that even two torpedo explosions shall not in most cases directly endanger their safety.

In considering *gunfire* we have to distinguish between armor piercing and shell effect.

The effect of armor-piercing shot is relatively local, but is liable to be much more deep-going than that of torpedo explosions. The effect of shell fire is more widespread, and is for heavy calibers quite comparable to that of a torpedo.

On ranges where the torpedo is effective, no armor of existing ships is proof against armor-piercing shot from modern heavy guns, and shell may be got through armor of medium thickness and more. Light armored and unprotected parts will be liable to destruction by all kinds

[1] J. T. Bucknill, Submarine Mines and Torpedoes, 1889, and Belle Isle Experiments, 1903.

of shell fire and shrapnel. Outside of torpedo ranges guns are still capable of inflicting fatal injury to any ship.

Thus the buoyancy and stability even in the best protected ships may be impaired by gunfire, and the vitals, although chiefly placed below water, are by no means out of reach of the guns. Since, however, most hits take place well above the water line, the effects of a single projectile will rarely be so fatal as those of a torpedo; but when we consider the aggregate effect of gunfire, the probability of fatal hits and the total sum of damage become great, on close ranges much greater than by torpedoes.

Unprotected or poorly protected ships are, therefore, liable to complete and rapid destruction when exposed to the fire from heavily armored artillery ships (*Variag*, *Rurik*), and there can be no doubt in this case of the superiority of the gun over the torpedo, since victory can be gained without much risk to the well-protected ships. Heavily armored ships are indeed able to stand a long-continued artillery fight, but even on ranges where the torpedo is inapplicable the best protected ships are exposed to ultimate disablement (*Cesarewitch*, August 10, 1904), and also within torpedo range gunfire will still maintain a decided superiority.

It might be objected that in spite of this superiority of the gun it might still be possible, on the principle of *la jeune école*, to construct fast and small torpedo vessels, capable of fighting the large battleships successfully. Protection should not be sought in armor, but in smallness, high speed, great number, and in short duration of attack, if possible, carried out by surprise.

The soundness of this idea so far as coast war is concerned has been proved in the Russo-Japanese War, where torpedo boats and destroyers have shown their usefulness; but for continuous service on the ocean at great distance from the base, such small and fragile craft are unsuited. Larger vessels of 2,000 to 3,000 tons displacement are here required, but with such great size the advantages due to smallness and great number are lost, and the vulnerability makes the type inapplicable to the work here required (*Shah* and *Huascar*).

Armored torpedo ships (*Polyphemus*), if of sufficient speed, steaming radius, and protection, would need to be very large.

Some see in the submarine torpedo boat the type that should lead us to abandon the large ships. As submarine boats are now, and as they are likely to be for some time, they seem, however, unfit for anything but harbor and coast work.

They will with other torpedo craft force the battleship to great caution in the coast war, but they cannot, in their present form, greatly endanger its safety on the high sea.

We conclude, therefore, that no satisfactory type of torpedo vessel, capable of securing command of the ocean, can be designed at the present time.

Bearing in mind also the fact that artillery is the only means of attack against forts, batteries, and troops ashore, there seems no escape from the conclusion that *the artillery must now as heretofore be the principal weapon of the sea-going battleship.*

We shall, therefore, now turn our attention to the artillery ship.

The Battery and Its Installation (Figure 4). — In choosing the battery we should consider primarily the work which it has to do, secondarily the ship in which it is to be placed. In other words, the ship should be designed to fit the battery and not conversely.

The battleship should be able to meet battleships of other navies on at least equal terms, and the caliber of the heavy guns should, therefore, not fall below that generally adopted, at present 12 inches. In view of recent progress in power of guns it might appear sufficient to carry 11-inch or even 10-inch guns, but in such case the effective range would be considerably reduced, and the ship thus placed at a serious disadvantage when matched against ships armed with 12-inch guns.

For the heavy guns the installation of two twin turrets, one at each end, is practically undisputed, and is, therefore, here accepted without further comment.

When we come to the secondary battery, opinions are divergent almost on all points, only the desirability of carrying a secondary battery is generally conceded.

This battery has its special work to do, which may be thus defined: —

1. Attack by armor-piercing projectiles on armor of medium thickness.

2. Attack by shell fire on unprotected and lightly protected parts.

The smaller the guns the more numerous and rapid firing they may be, and the more numerous the rounds fired per gun, and thus the more general and widespread their effect; this is of importance in view of the large areas left protected by secondary armor or unprotected in most existing battleships.

It must, however, be borne in mind that in recent ships we find a

much more extensive protection by armor of medium thickness (6-inch and 7-inch) than was the case only some ten years ago, so that now no part of any importance is left lightly protected.

Hence shell fire by common and high explosive shell from rapid-firing guns is incapable of inflicting serious damage to recent battleships, and even armor-piercing shot and shell must be of more than medium caliber in order to do any work of importance on such ships. None of the existing rapid-firing, hand-worked guns seems strong enough for this work, for although the 7-inch and 7.5-inch guns may perforate the secondary armor even at ordinary fighting ranges at sea, they will not do so generally or with a sufficient excess of energy.

Hence it is advisable to go to greater calibers and therefore to mechanically worked guns, and once we take this step and pass to the turret installation we may as well choose a gun of considerably superior power, since the rate of fire will not thereby be materially lessened.

At the present time no gun seems better adapted to fulfill the functions of the secondary gun than the Vickers 9.2-inch gun, which seems to combine in the highest degree rapid firing with high penetrative power — five rounds in one and one-half minutes under service conditions, 11-inch K. C. steel,[1] direct impact 3,000 yards. It is, however, quite likely that a few years hence we shall find the 10-inch or even a larger gun more suitable.

Other important arguments in favor of going up to a rather large caliber are found in the relation between caliber and protection, to be discussed hereafter, and in the fact that the efficacy of the cap increases with the caliber.

To carry a battery of smaller caliber, such as 6-inch, besides these "semi-heavy" guns appears irrational; they will not be able to do any serious work on battleships at ordinary fighting ranges, and they will, as shown hereafter, in point of protection be a source of weakness.

The same reasons which have led us to mount the heavy guns in *twin turrets* must hold with equal force with machinery-worked, semi-heavy guns. The only weighty objection to the twin installation in this case seems to be the reduced rate of fire. If a fully satisfactory twin installation for guns of this or similar size can be designed, where the rate of fire per gun approaches that of the present single turret installation for 9.2-inch guns, it must be preferable.

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[1] K. C. stands for Krupp cemented.

In order to secure the important artilleristic advantages of high gun position and a great arc of fire, the secondary gun turrets should, like the heavy gun turrets, be placed on the main (weather) deck. It seems, indeed, under any form undesirable to mount any important guns on the gun deck, because they may here be difficult to work in rough weather.

Two and preferably three twin turrets should be carried on each side.

A battery of numerous light guns and machine guns should be carried for use against torpedo craft and light cruisers. This battery, being the most effective defence against torpedo boat attack, should be carefully placed and distributed so as to secure a concentrated fire in all directions round the ship.

The torpedo armament should consist of four to six submerged torpedo tubes, and the bow should be provided with a well-supported ram.

2. Speed and Steaming Radius

The speed and steaming radius should be chosen with regard to tactical and strategical requirements; they are, like the armament, independent fundamental elements of the design. The maximum speed is essentially a tactical quantity, properly determined by the naval officer, while the steaming radius is primarily a strategical quantity, determined by the naval administration on the basis of the naval policy of the country. The two elements are, however, indirectly connected, for the cruising speed, at which the steaming radius is to be covered, is, for proper economy, a function of the maximum speed. In the British navy it is reckoned that cruising takes place at one-fifth full power.

The *maximum speed* should be chosen the same as that of existing recent battleships, that which may be considered the standard battleship speed of the day. This speed has been constantly increasing, but is generally well defined, and is at present eighteen knots. To fall below this point must prejudicially affect the usefulness of a ship, tactically and strategically; the mobility of other faster ships with which it may be in squadron will be hampered, and it will be exposed to being cut off or overtaken by superior forces.

It seems, on the other hand, undesirable to exceed this standard speed, since even a small addition to the maximum speed can only be obtained either by an undue expenditure of power, entailing a corre-

sponding reduction in the purely military elements, or else by a considerable increase in size (length), by which the greater speed can often be obtained with but a moderate addition to the horse power. Such increase in size, leaving the military elements unaltered, would, however, virtually amount to a reduction in these latter, since for a given expenditure the number of ships would have to be reduced.

Thus there would in any case be a reduction in fighting strength, and the increase in speed would be unable to compensate for this loss. Speed is in itself a fictitious quality; it acquires value only through the implied mobility of the battery. Hence increased importance of the battery justifies increase in speed, but it is irrational to increase speed at the expense of armament. An advance in speed beyond that usually adopted should, therefore, follow only after an improvement in armament and protection has necessitated an increase in displacement, and even then only in a conservative measure and with due regard to the naval policy of the country.

Steaming Radius. — The battleships of all great naval powers may be called upon to operate all over the globe, and in choosing the steaming radius the distance between possible coaling ports has to be considered. A nominal radius of 8,000 miles at about ten knots, which probably corresponds to an actual radius of about 5,000 miles, may be considered generally sufficient.

3. Nautical Qualities, Principal Dimensions, and Size

Conditions on the ocean are the same for all ships, large and small; the state of wind, weather, and sea, which so largely influences the behavior of ships and the service and life on board, enters, so to speak, as a constant factor in the design. If, therefore, the ship is to be serviceable as a gun platform for a battery of given character and size, she must possess certain nautical qualities, which to a great extent will be determinative of the form and size of the ship.

Similarly the speed, if it is to be attained economically and without interference with the service of the guns and the ship, must exert an important influence on the design.

That a relation must also exist between steaming radius and size is obvious.

a Relation between Armament, Nautical Qualities, and Size.

The nautical qualities referred to are the following: —

Steadiness, required for good gun practice; secured by giving the ship a great period of oscillation.

Stiffness, preventing a too great heel when turning and when side compartments are flooded; secured by a good metacentric height.

Dryness, allowing the unhindered use of the guns even in rough weather.

Strength, required to withstand the stresses set up by firing the guns.

The claims to steadiness and stiffness are conflicting, but the larger the ship, the more completely may both be satisfied. The reason of this is, that in similar ships both the period of oscillation and the metacentric height increase with size, the latter directly as the linear dimensions, the former as their square root.

The quality of dryness is secured by a great freeboard and, so far as the artillery is concerned, by a high location of the guns. This latter feature is of advantage also because the guns obtain thereby a more commanding position.

The freeboard is naturally greater in the larger ship, and, since the moment of stability increases as the fourth power of the linear dimensions in similar ships, we may mount the same guns considerably higher in a larger ship than in a smaller one without impairing the stability.

The larger ship is better able to stand the strains due to firing a certain gun than the smaller ship.

Finally, we have to take into account the important fact that the behavior of larger ships in a seaway is better than that of smaller ships even of the same period, due to the smaller effective wave slope.

Summing up, we may say that *the large ship is intrinsically more suitable as a gun platform than the small.*

Only in one respect is the larger ship at a disadvantage as a gun platform, namely, in that its maneuvering power is smaller. On the great fighting ranges usual in the open sea, this drawback is, however, of secondary importance. Since the importance of each round increases greatly with the caliber of the gun, and since larger guns require for their effective use a better gun platform than smaller guns, we arrive at the corollary, that *the larger the guns are, the larger should be the ship to carry them.*

This principle cannot be stated in an exact, quantitative manner, but experience affords sufficient guidance for its application.

A certain increase in *weight of armament,* whether brought about by an increase in caliber or in number of guns, will necessitate a much greater increase in displacement, if all the other elements of the design — speed, steaming radius, protection, etc. — are to be preserved unaltered. By an ingenious method, devised by Mons. I. A. Normand, based on a partial differentiation of the weight equation, we are able to estimate this increase very approximately; it is found in a battleship to be about three and three-tenths times the increase in weight of ordnance. Since, however, the weight of armament is about 9 per cent. of the displacement, we find that the percentage of increase in displacement is barely one-third of the percentage of increase in weight of armament. This is strictly true only so long as similarity is preserved and only for moderate changes, but it affords sufficient ground for the general proposition that, quite apart from the question of behavior at sea, *the larger ship is, other things equal, able to carry a relatively much greater weight of armament than the smaller.* Increase in power of battery is an important tactical advantage, since it facilitates concentration of attack.

b. Sea Speed and Size

By increasing speed, the pitching, rolling, and tremors to which a ship is subject in a seaway become more violent, the strains on the structure and the fatigue to the crew more severe, and the spray and solid water shipped are apt to increase; but the larger the ship, the better will be the behavior.

In a seaway the increase in resistance to propulsion is much greater for the smaller than for the larger ship; and hence the important advantage for the latter, that in this class, under average service conditions, the sea speed bears a much greater proportion to the maximum trial speed than in the former.

c. Speed and Length

The size of the ship is also in another way intrinsically connected with the speed, namely, through the length, which more than the other principal dimensions influences the resistance. For economical propulsion the length in the water line must exceed a certain figure, which in

ships of full form, such as battleships, is given very approximately by the rule that the square root of the length reckoned in feet should somewhat exceed the speed reckoned in knots. This is because at about this speed there is a hump in the resistance curve due to wave making.

In most existing battleships we find that the maximum trial speed is about 9 per cent. less than the square root of the length, but in some ships this percentage difference is much greater. Thus in the *Connecticut* it is 15 per cent., and judging from model experiments this great advance in length relative to speed has given a great gain in economy of propulsion.

d. Speed and Freeboard

The freeboard in the fore part of the ship must be greater the higher the speed is in order to avoid excessive wetness and resistance to propulsion. Experience is our only guide in this respect, but furnishes ample material from which to judge.

e. Steaming Radius and Size

Supposing the coal supply to form a certain percentage of the displacement, then since propulsion at a given speed is relatively more economical in the large ship than in the small one the former will be able to cover a greater distance.

f. Numerical Values

It remains by way of illustration to apply the foregoing general principles and considerations to the concrete case of a battleship carrying an armament as specified above and of a speed of eighteen knots. Although we are yet unable definitely to determine the dimensions or the displacement, we may now assign minimum values, based on practical experience, to several important elements of the design.

The period of oscillation for a single swing should, in accordance with experience, be not less than six and one-half seconds, which should indeed be regarded as an extreme lower limit.

Both primary and secondary guns should be placed at a height above water of not less than about 25 feet. Since all these guns are to be mounted in turrets on the main deck, it follows that this deck

should be made continuous from end to end. The freeboard would accordingly be some 17 to 18 feet, which corresponds well with the requirement that for a speed of eighteen knots the freeboard in the bow ought not to be less than 18 to 20 feet.

From what was said above, the length in the water line should, with eighteen knots speed, be not less than 400 feet, but may, as far as speed is concerned, be made with advantage 450 feet, and perhaps even greater.

4. Protection

A warship is subject to *submarine attack* from mines, torpedoes, and ramming, and is, like all other ships, exposed to the dangers of collision and grounding. Above the water and to some distance below the water line it is exposed to *artillery attack*.

Protection against submarine attack is attained chiefly by water-tight subdivision, protection against artillery fire chiefly by armor; but in the region of the water line subdivision and armor concur with and supplement each other in the protection of buoyancy and stability.

It is the object here only to state general principles, and on the basis of these to outline a logical system of protection.

A. Water-tight subdivision

The principal object of water-tight subdivision is to limit the inflow of water in case of damage to the bottom. In a sea-going battleship the most important effects of flooding are those affecting the *stability*, on which the efficiency and, ultimately, the safety of the ship largely depend. The buoyancy in this class of vessel has an ample reserve for all contingencies and need not generally be considered.

It is therefore necessary to secure a certain measure of stability in damaged condition, and hence, as a basis for the design of subdivision, we must make assumptions as to: —

1. The probable nature and extent of damage which we claim that a battleship shall be able to sustain without being put out of action.

2. The loss in stability which we consider will still leave the ship in a fit condition for action.

Judging from recent war experiences, it seems necessary to claim that a battleship should, under most conditions, be able to stand a single blow from a mine, torpedo, or ram without being put out of action.

The blow of the torpedo and ram is usually delivered against the side of a ship at a moderate depth, and the same is true for contact mines in general; only bottom mines are likely to explode *under* the bottom of a ship, but in the localities where such mines are placed sea-going battleships ought not to operate except on rare occasions and after due precautions are taken.

We shall therefore assume the damage to extend inwards from the side, and, admitting that the blow may strike at one of the principal transverse bulkheads and that it may extend so far that the inner lateral bulkhead is damaged, we must be prepared for simultaneous flooding of two large hold compartments and adjacent wing compartments on one side.

Under artillery attack the ship should be able to stand complete riddling in the region of the water line of the parts not protected by heavy armor. As shown hereafter, only the ends should be thus lightly protected. We must also be prepared for several perforations of the heavy side armor at the water line.

In case of grounding the ship should be able to stand tearing up of the outer bottom for half the length of the ship, or tearing of a shorter length of the outer bottom with simultaneous damage to the inner bottom in three of the large internal compartments.

Under each of these conditions of damage the permissible *limiting effects on stability* are proposed, as follows: —

The loss in metacentric height should not, after flooding is completed, exceed 25 per cent. of its initial value.

The heel should not seriously interfere with the general service of the ship or the guns; it should thus be within the maximum depression of the guns. The lower edge of the side armor should still be well immersed. These claims may be satisfied if the heel does exceed about 5°.

The change of trim should not be so great as to immerse the deck nearest above the water line at the ends. This deck is usually placed level with the flat top of the protective deck, about 2 to 3 feet above water.

It may here be proper to state the further claim that tanks in the wings and at the ends should be provided for quickly righting the ship and for placing her on even keel

It will probably be admitted that if the effects of submarine and artillery attack here specified are not exceeded the ship will still be able to face all conditions of weather and to continue a fight.

As shown in the paper on water-tight subdivision, which I had the honor to read before the Society of Naval Architects and Marine Engineers last year, the loss in metacentric height will not in ships as now usually constructed exceed the proposed limit, nor will the change of trim need to exceed the limit in battleships as recently designed; but the most important claim, that to a moderate heel, is far from being fulfilled, at least in ships where a centre line bulkhead is fitted. As shown in that paper, flooding of two side boiler rooms in such a ship is enough to produce a heel of more than 9°, practically putting the ship out of action; and if, moreover, side bunkers and adjacent wing compartments are flooded, the ship will be brought to an extremely critical condition. The war in the East has taught us how frequently ships may be exposed to mine and torpedo attack, and it is, therefore, absolutely necessary that something should be done to improve the design of battleships in this respect.

First it is proposed *to increase the metacentric height by an increase in beam.* The metacentric height in recent battleships varies from $3\frac{1}{2}$ to $4\frac{1}{2}$ feet, and may by an addition to the beam of some 3 or 4 feet be brought up to about 6 feet. Since it is undesirable to fall below the proposed limit for the period of oscillation, six and one-half seconds, the stiffness should not be increased beyond a certain point, but as the radius of gyration is also increased a metacentric height of 6 feet would for a large battleship probably not be too great.

Even with the greater stiffness thus obtained it is impossible to arrive at a satisfactory solution in ships with centre line bulkhead, for the heel which would be produced by the blow of one torpedo or mine might still far exceed the specified limit. Hence *no centre line bulkhead should be fitted* except where absolutely necessary, *i. e.*, in twin-screw ships only between engine rooms.

In doing away with this feature the boiler arrangement now frequently adopted, where two rows of boilers have common fire rooms, would have to be abandoned in order to avoid excessive size of boiler rooms, and consequently there would generally be a loss in space. This loss is partly regained by omission of the centre line bulkhead, and, by arranging the boilers as shown on the adjoined sketch (Figure 1), the space occupied by passages for communication between boiler rooms might be saved. Moreover, by the use of oil for *mixed combustion* (spraying oil over the coal bed), a method used with success in the German and Italian navies, a saving in bunker space might be effected

by which the transverse bunkers might be shortened or done away with if the oil is carried in the double bottom. According to the recommendation of the United States Naval Liquid Fuel Board, more roomy boiler space is highly desirable, and this may, according to the board, be obtained without increasing the total space occupied by the boiler plant by a higher forcing of the boilers. Such forcing can readily be effected by mixed combustion If a satisfactory installation for the *exclusive use of oil* can be developed, the gain in space will, of course, be still greater.

The engine rooms in modern twin-screw ships constitute in point of stability by far the greatest danger, being about 30 to 50 per cent. greater than the boiler rooms, and being necessarily separated by a centre line bulkhead.

Flooding of one engine room in a modern battleship may be expected to produce a heel of about 6°.

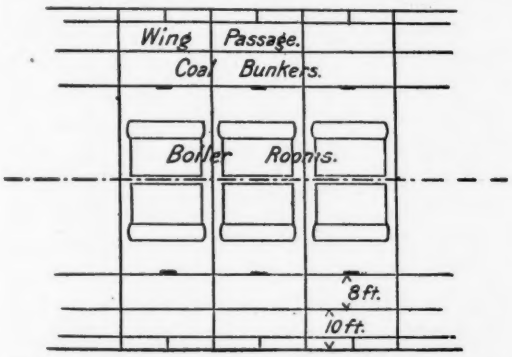

FIG. 1.—HORIZONTAL SECTION SHOWING ARRANGEMENT OF BOILERS, BULKHEADS, AND WING PASSAGES

A further subdivision of the engine power, which is also for other reasons desirable, seems, therefore, almost a necessity with regard to safety. Four engines on two shafts, as in the *Brooklyn*, would solve the difficulty, but mechanically the triple-screw system probably offers the best solution, at least so long as reciprocating engines are used.

The double bottom should be complete, extending from armor shelf on one side to armor shelf on the other; it should be subdivided by numerous water-tight frames and two water-tight longitudinals, one at each turn of bilge. The vertical keel should not be water-tight. (See Figure 2.)

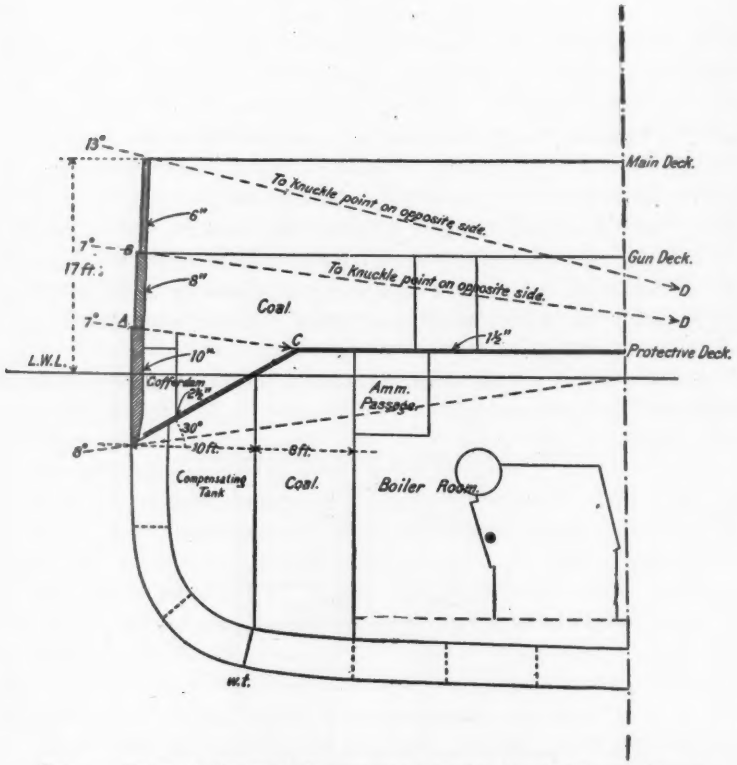

FIG. 2. — DIAGRAM SHOWING DISTRIBUTION OF ARMOR AND WATER-TIGHT SUBDIVISION IN A SEA-GOING BATTLESHIP

Lateral Bulkheads. — No obstructions are able to withstand the enormous pressures near the centre of explosion of a torpedo or mine; they will, on the contrary, serve to transmit the energy either by *concussion*, as in case of transverse bulkheads and layers of coal, causing damage to internal structures, or by heavy *fragments being detached* and hurled into the hold, as is likely to happen with armor placed on or near the outer shell. The more freely the gases are allowed to expand inside the ship the less must be the external work done by the explosion on the structure. Strengthenings, armoring, or other obstructions placed near the outer bottom as protection against explosions appear, therefore, to constitute only a source of danger. If these

views are correct — and they seem fairly supported by the few experiments that have taken place in this direction — the outer shell should not have more than ordinary thickness, the connection between the double bottom and the inner lateral bulkheads should not be too intimate, and the spaces next to the inner bottom, here referred to as *the wing passage spaces*, should be of great depth and as far as possible be left unoccupied. The wing passage bulkheads should be fitted at a distance from the outer shell of not less than 10 to 12 feet, and should extend from fore end of forward magazine to after end of after magazines; they will in this location also have good chances of remaining intact when ramming.

Since it is quite likely that the wing passage bulkhead will be damaged by an explosion, another bulkhead, *the side bunker bulkhead*, should be fitted along the boiler and, if possible, the engine rooms at a distance of about 18 feet from the outer shell. This bulkhead, being thus about 20 feet from the centre of an explosion, will be exposed to only relatively moderate pressures, and if strongly constructed it should have good chances of remaining intact or of receiving only light damage. It seems likely that extra strengthenings and even armoring with plates of mild, tough steel will prove very effective on this bulkhead, but only experiments can settle this question. The *main transverse bulkheads* below the armor deck should be left without doors, or, if doors must be cut, they should be placed at a high level.

The system of water-tight *subdivision above the protective deck*, usually found in recent battleships, seems sufficient to provide for the probable damage in the region of the water line specified above.

It is clear that the ship which is to fulfill the claims so far formulated, if it is to have a proper armor protection, must be of the largest class.

The proposed location of lateral bulkheads and the great metacentric height will probably make it necessary to go to a beam of about 80 feet.

Let us assume a displacement of about 17,000 tons, and that a torpedo explodes at one of the main transverse bulkheads between boiler rooms, whereby two wing compartments and two side bunkers are likely to be flooded. The heel would then by reasonable subdivision be about 5°. In case the inner bulkhead is seriously damaged, two boiler rooms would, moreover, be flooded; but this would not augment the heel, and by admitting water into adjacent coal bunkers and wing spaces on the opposite side the ship might be nearly righted again.

All wing passage spaces along the broadest part of the ship should be capable of serving as compensating tanks, and should be provided with powerful means for flooding and emptying.

The great danger from explosions occurring near magazines makes it very desirable to place the wing passage bulkhead at least 12 feet from the side along the magazines, and it is better not to stow any explosive matter outside this bulkhead.

The damage by grounding assumed above would cause no heel but only a bodily sinkage, which, by flooding of three boiler rooms, would not need to exceed 10 per cent. of the draught.

B. PROTECTION BY ARMOR

a. Relation between Armament and Armor

It is the object of all strategical and tactical maneuvers to bring the greatest possible force to bear at the point of contact with the enemy. Battle with a more powerful enemy is generally avoided, except where special circumstances justify or necessitate such course, and this contingency may, therefore, be considered an exception on which it would not be wise to base the protection of any type of warship. On the other hand, in a fight with a ship carrying a lighter battery a warship ought to be at an advantage also in point of protection, since the stronger unit will otherwise be exposed to destruction by the weaker unit.

We are, therefore, in good accordance with fundamental military principles if we base the protection on the assumption, that the antagonist is a ship of equally powerful armament, *i. e., the protection should match the guns carried by the ship itself.*

A vessel thus protected will always be at an advantage when matched against the over-gunned or over-protected ship of same size, since for a given weight of the military elements the over-gunned ship will not be adequately protected, the over-protected ship will not be adequately gunned.

Since the penetrative power of guns and their general effect vary greatly with the range and other conditions under which fighting takes place, the claim that the protection shall match the guns must be referred to certain standard conditions. As stated above, we shall here choose as standard the *probable average conditions*, to be defined hereafter.

History shows that the ships which are able longest to sustain the stress of fighting have the best chances of carrying home the victory; a lucky shot or a lucky broadside may in some cases be decisive, but, again, the design should not be based on such exceptional and uncertain conditions. The protection should, therefore, leave no weak point, but be so distributed that it will enable the battleship to keep up a *long-continued fight.*

Summing up, we may therefore state as a general principle that *battleships should be so protected that they can keep up a long-continued fight with an equally powerfully armed antagonist under average conditions of fighting.*

This principle must indeed hold good for all warships armed with artillery. For the sake of briefness the protection given according to this rule shall be referred to hereafter as "*corresponding protection.*"

Having thus shown that the protection should be a function of and in a broad sense proportional to the armament, it remains to qualify this relation further, and we shall begin by defining the standard conditions on which it should be based. It cannot fail that here, as in the case of other numerical values chosen in this paper, opinions may differ, but such difference cannot affect the underlying principles which the assumed figures merely serve to illustrate.

b. Average Conditions of Fighting at Sea

Average fighting range, variously estimated at 3,000 and 4,000 yards, is here assumed to be 3,500 yards. (During the battle off Port Arthur, August 10, 1904, the fighting distance is stated to have varied from 3,500 to 8,000 yards.)

Average angle of impact on vertical armor, 30° with normal. Average angle of impact with flat decks, *i. e.*, decks that are horizontal when ship is upright, is assumed 7°.

This angle is made up of two parts: first, the angle of fall on the horizontal plane, due to curvature of trajectory and difference in level between gun and target, estimated at 2°; and secondly, an angle of 5° to allow for rolling, pitching, heel by turning, etc. To an average roll of 5° will correspond maximum rolls of about 10°; when ships roll beyond such angles the fire is not likely to be effective. The angle of 7° is hereafter referred to as the angle of fall.

c. General Distribution of Armor

The protection can only be *relative, i. e.*, we cannot in an absolute manner protect the ship against gunfire even under average conditions. Some parts may be protected up to this point, but the armor cannot and ought not to be made equally thick everywhere, and other parts must, therefore, be left more or less exposed. It seems rational to make the *armor protection proportional to the relative importance of the part to be protected.*

It is, however, difficult to gauge this relative importance; the quantities to be compared are in several cases entirely incommensurable, and here again only general considerations can serve for our guidance.

A warship should not be regarded only as a conglomeration of mechanisms more or less independent of one another, but much more as an organic whole, a living organism, where the destruction of any member will act detrimentally, not only directly but also indirectly, on the strength and vitality of the whole.

The protection should be conceived accordingly, not by considering each member separately, but by weighing its importance in relation to the warship as a whole.

The *crew* is virtually the most important vital of a ship; in it is embodied the brain, nerve, and moral force of the ship considered as an organism, and its protection is, therefore, of primary importance. Now, the crew is scattered all over the ship; where there are machinery, guns, or other appliances in function there must be men to work them, and hence the men receive the same protection as the part or appliance of the ship to which they belong and of which, in a certain sense, they form part, and, as stated above, the most essential part.

Thus, speaking generally, since the more important persons are those that are working the more important parts, we shall, by properly distributing the armor on the *matériel*, also therewith distribute it properly on the *personnel*. It must, however, be borne in mind that casualties exert a far stronger moral influence on the crew than does the destruction of *matériel*. The wounded have to remain on board; the crew of a ship is limited, and since no reserves can be carried the losses cannot, as on shore, be made good during action. Hence the life of each man on board ship has a great intrinsic military value, and, therefore, where it is necessary to station men in action it is also necessary to provide a certain protection, or, conversely, the service should

be so arranged that no men will have to stay permanently in the unprotected or lightly protected parts of the ship.

Turning to the *matériel* we shall first discuss the relative importance of *ship and guns*, understanding by "ship" not only the hull but all that goes to work it in action, notably the vitals.

When we considered the nautical qualities and the size of the ship we looked upon them as subservient to the battery, as a floating gun platform; but when we consider the protection we have to base our judgment on the value of the ship, not only as a gun platform, but also as a safe carrier of crew and vitals.

We have to bear in mind: —

That the protection of the greatest part of the crew and the safety of the entire crew are inseparably connected with that of the ship.

That the use, efficiency, and ultimately the existence of the battery depend on the maintenance of the stability and the preservation of the vitals, while on the other hand, even if the guns are put out of action, the ship may still be able to use ram and torpedoes or to withdraw.

Hence the protection of the ship must take precedence in importance over that of the guns.

The vitals and the stability should, therefore, receive the heaviest armor protection, the heavy guns a somewhat reduced protection.

In comparing the relative importance of *heavy and secondary guns* we have to take into account the penetrative power, the rate of fire, and the arc of training; but since the greater rate of fire of secondary turret guns of great caliber is about neutralized by their smaller arc of training, *we may reckon the relative importance of the guns to be proportional to their penetrative power.*

The protection should be proportioned accordingly, but since the secondary guns with their crews are exposed also to the fire from heavy guns they will thus be placed at a disadvantage, and the more so the more their caliber falls below that of the heavy guns. It appears, indeed, impossible to obtain a fully satisfactory system of protection with a heterogeneous battery. What was said above concerning exposure of the crew is here particularly applicable, for not only must smaller guns be given less protection than larger, but, being more numerous, they entail the exposure of a greater number of men. This seems an important objection to the batteries of numerous rapid firers, now so generally carried by battleships as secondary armament.

The existence of different calibers of guns in the same ship is,

therefore, in point of protection a source of weakness, and the more so the greater the difference in caliber is.

Hence in deciding the caliber of secondary guns it should be chosen as near to that of the heavy guns as due regard to its characteristic features will permit; these features are rapid firing and greater number of guns, hence greater volume of fire and more widespread effect.

d. Protection of the Ship

It is a fundamental principle in armor protection that all effects of gunfire, and notably shell explosions, should, as far as possible, be kept outside the ship, and that hence, speaking generally, *external armor is preferable to internal armor.*

Side armor must, therefore, be the most effective form of armor, but since it cannot everywhere be made thick enough to prevent shell from passing through and bursting inside, and since projectiles passing over its edge may still reach the vitals, it is necessary further to protect these latter by an armor deck.

In the Appendix[1] is shown that a given weight of side armor will, on the whole, give as good a protection against armor piercing as the same weight of deck armor, and to this must be added that side armor protects not only the vitals, like the deck armor, but also the buoyancy and the stability, and that it serves to keep shell explosions outside the ship. Hence *the armor weight should chiefly be placed on the side, and no more weight be given to the armor deck than necessary to its function as a splinter deck.*

The armor deck will, of course, at the same time assist the side armor in protecting the vitals against armor-piercing shot.

The lower the protective deck is placed the better it will be sheltered and the more completely will it coöperate with the side armor, hence it should be placed as low as regard to stowing the vitals will permit, and should join the side armor at its lower edge. These claims lead to the usual form of protective deck — sloping sides and a flat top, some 2 to 3 feet above water.

For the entire length of *the main group of vitals*, magazines, machinery, and electric plant, the protection of which shall be first considered, *i.e.*, between the extreme end of magazines forward and aft, the side

[1] For Appendix, see Transactions of the Society of Naval Architects and Marine Engineers, 1904, 12, pp. 101–106.

armor should be carried to such a height that projectiles coming at the average angle of fall of 7° and passing over its upper edge should be unable to strike the protective deck. Referring to the diagram (Figure 2), this height is determined by the point *B* on the side, found by drawing a line, *DB*, through the knuckle point on opposite side of the protective deck at an inclination of 7° with the deck. The point *B* is seen to fall very near the gun deck line, which shall be considered the upper edge of this part of the side armor.

The angle of 7° is, however, a hypothetical figure; projectiles may still under certain circumstances pass over the side armor thus determined and reach the protective deck. Not only armor-piercing shot but also shell, and notably high explosive shell, when exploding in direct contact with the deck, may break through the deck and damage the vitals. It is, therefore, necessary to armor the side between gun and main deck in the region of the vitals, and the armor should here be sufficient to bring all shell to explosion, and preferably so as to keep out all common and thin-walled high explosive shell.

Behind the side armor we find the barbettes, uptakes, communication tubes, etc., all of which must be given protection according to their importance; the presence of the side armor will, however, permit a great reduction in the local protection on these items.

In most combinations of external and internal armor the walls are not parallel, and hence the great advantage that normal impact on both is impossible. In case, for instance, of barbettes placed on the broadside behind side armor, nearly normal impact on both side and barbette can be obtained only by striking nearly normally a limited region of the front of the barbette, and the armor on the remainder may, therefore, be very much reduced in thickness. In order to shelter the vitals against longitudinal fire, transverse armor bulkheads should be placed at the extreme ends of magazines forward and aft, extending from protective to main deck. These bulkheads complete the vertical rectangular wall which surrounds the vitals and forms a redoubt rising from the protective deck, which it serves to shelter, at the same time providing ample protection for the stability.

The lower edge of the belt, and therefore also the edge of the protective deck, should be at such a depth below water as will allow for rolling and wave motion; this is fairly attained if it emerges only at an angle of roll of 8°.

Since the vitals should be absolutely protected under the assumed

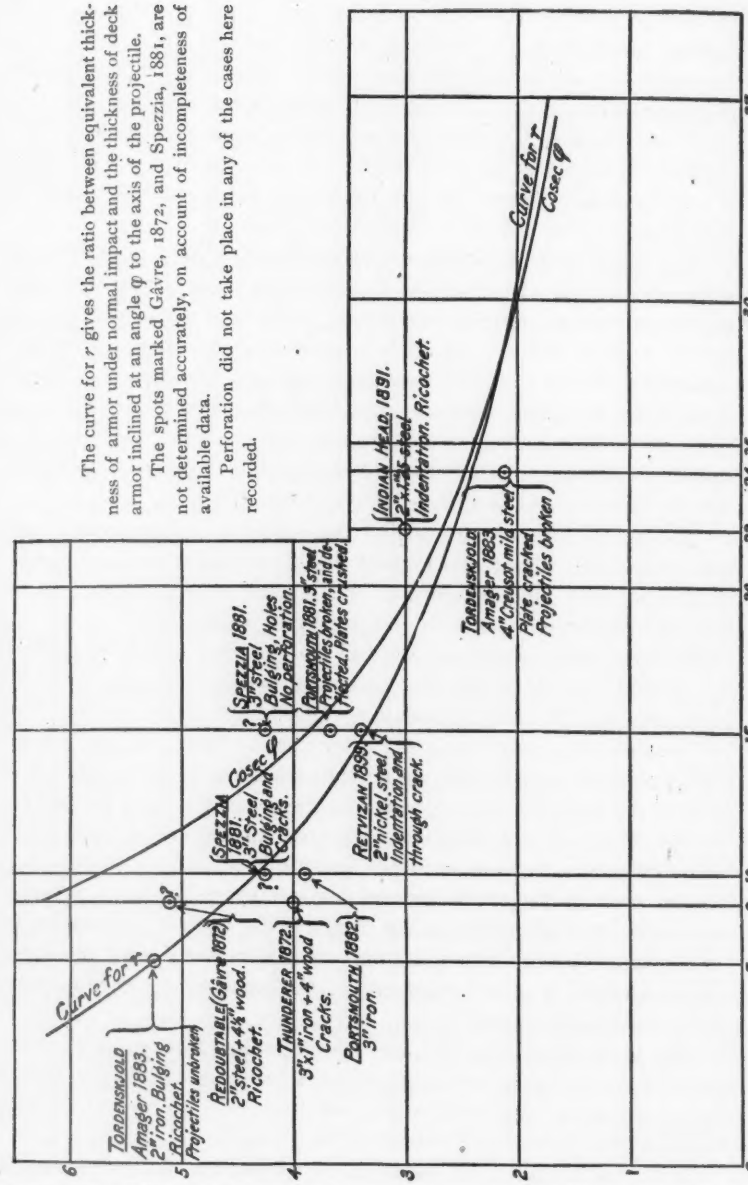
The curve for r gives the ratio between equivalent thickness of armor under normal impact and the thickness of deck armor inclined at an angle φ to the axis of the projectile.
The spots marked Gâvre, 1872, and Spezzia, 1881, are not determined accurately, on account of incompleteness of available data.
Perforation did not take place in any of the cases here recorded.
Curve for r
Curve for r Cosec φ
Torpedoboat Amager 1883. 2" iron. Bulging. Ricochet. Projectiles unbroken
Redoutable (Gâvre 1872) 2½" steel + 4½" wood. Ricochet.
Thunderer 1872. 3½" iron + 4" wood. Cracks.
Portsmouth 1882. 3" iron
Spezzia 1881. 3" steel. Bulging and cracks.
Retvizan 1899. 2" nickel steel. Indentation and through crack.
Spezzia 1881. 3" steel. Bulging. Holes. No perforation.
Ponsonby 1881. 5" steel. Projectiles broken, and decked. Plates crushed.
Torpedoboat Amager 1883. 4" Creusot mild steel. Plate cracked. Projectiles broken.
Indian Head 1891. 2½" nickel steel. Indentation. Ricochet.
Ratio between Thickness of Equivalent Armor at Normal Impact and Thickness of Deck Armor
Angle between Axis of Projectile and Plate : φ

FIG. 3.—DIAGRAM SHOWING STRENGTH OF DECK ARMOR COMPARED WITH SIDE ARMOR

average conditions against the 12-inch gun, the total protection afforded by deck and side armor in the region of the vitals should be equivalent to not less than 14½-inch K. C. armor, this being the estimated penetration of recent 12-inch guns on 3,500 yards at 30° angle of incidence. The cap is here reckoned effective up to this angle, an assumption which is probably on the safe side.

According to what was said above, the thickness of the armor deck should be as small as regard to its function as a splinter deck will permit. It is proposed to give the slope 2-inch armor, assuming a slope of about 30°, and the top 1-inch armor, both laid on an ordinary ½-inch steel deck. As shown in the Appendix, the armor on the slope should be of a hard quality and very efficiently supported; that on the top should be of mild but tough steel; also it is shown that the equivalent thickness of vertical armor may be estimated at 3-inch K. C. for the sloping and 5-inch K. C. for the flat part. Consequently the corresponding regions of the side armor may be reduced by these thicknesses.

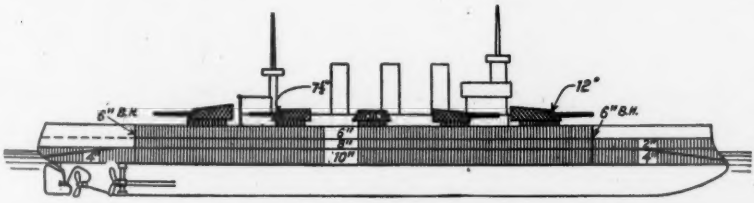

FIG. 4. — DIAGRAM SHOWING DISTRIBUTION OF ARMOR AND ARMAMENT

Displacement about 17,000 tons. Approximate principal dimensions, 460 x 80 x 24′ 6″. Armament 4–12″, 12–9.2″, a number of 3″ guns and machine guns. Speed, 18 knots. Fuel capacity (coal and oil) equivalent to about 2,200 tons of coal.

The side armor is, therefore, naturally divided into three strakes: a lower one which coöperates with the sloping armor, referred to as the "water line belt," a second which coöperates with the flat part of the armor deck and which shall here be called the "middle strake," and an "upper strake" extending from gun to main deck, which serves as a margin on the middle strake and more particularly as protection against shell fire. (See Figure 1.) The boundary between the belt and the middle strake is found by drawing a line, *CA*, through the nearest knuckle point of the protective deck at an angle of inclination of 7° to the deck.

If we reckon that the protection which the vitals receive from backing, plating, and coal is equivalent to 1½-inch K. C. armor, we arrive at

a thickness of the belt of 10 inches and of the middle strake of 8 inches. Since the upper strake ought to keep out all thin-walled shell, its thickness should probably not be less than 6 inches. On account of the sheltered position of the transverse armor bulkheads their thickness need hardly exceed 6 inches throughout.

Turning to the protection of *the ends*, it will be seen that, with the great extension and height of the heavy redoubt here proposed, the ends, and notably the after end, are relatively unimportant as far as stability and buoyancy are concerned, and apart from the steering gear no important organs need be found here. The protective deck should, however, be continued to the ends, but since it may here be placed much lower than at amidships, and since the ship is here of small breadth, the height of side armor necessary for protection of the deck may be much smaller. The ends should, in the water line, not be exposed to riddling by light guns and by high explosive shell from rapid firers, and the belt should, therefore, be continued right to the stem and stern; a uniform thickness of 4 inches is probably sufficient for this purpose. The middle strake should be continued to the bow and be given a uniform thickness of some 3 inches to 2 inches. The steering gear should receive an extra protection by a thickening of the armor deck.

In many ships we find *a second armor deck* fitted on top of the vertical armor. As protection against plunging *projectiles passing over the edge of the side armor*, such a deck will not offer more resistance to armor piercing than if used as an addition to the lower armor deck. As to shell fire, there seems very little danger of shell exploding in direct contact with the lower armor deck, even in the absence of an upper armor deck, with the great height of vertical armor here proposed. Where a battery of secondary guns is placed on the gun deck an armored main deck would no doubt be of some use, but whether it would really be able to protect against the effect of high explosive shell bursting in contact with it seems doubtful.

When we come to consider the more usual case, that of *projectiles entering the ship by perforation of the side armor*, we find that not only will the upper armor deck be useless, as in case of armor-piercing shot, against which it does not assist the lower protective deck, but in case of shell explosions occurring between the two decks it is likely to be positively injurious by preventing the upward expansion of the gases.

Also, with regard to weight distribution (stability), it is more desirable to place the armor on the lower deck.

Hence *all deck armor should be concentrated on one protective deck, placed as low as due regard to an efficient installation and service of the vitals will permit.*

It remains to state that the *funnel casings* should be protected against shell fragments by 1-inch plating up to height of main deck.

The *conning tower*, being the centre from which the activity of the whole ship is governed, is essentially a vital organ, and should not be given less than 12-inch K. C. armor.

e. Protection of Guns

In accordance with the principles stated above, it is proposed to give the heavy guns and their installations a protection equivalent to about four-fifths that of the vitals, *i.e.*, 12-inch K. C. armor. This would, under the assumed average conditions, practically render them safe against armor-piercing shell from the 12-inch gun.

Since the penetrative power of the 9.2-inch guns on 3,500 yards is barely two-thirds that of the 12-inch guns, we find the corresponding protection of 9.2-inch guns to be $7\frac{1}{2}$-inch K. C. These are maximum thicknesses to be adopted on front of the hoods and on the barbettes where these are exposed directly to the fire of the enemy. From some feet below the main deck it appears that the thicknesses can safely be reduced on heavy and secondary turrets to 8 inches and 5 inches, respectively, and again from a couple of feet below gun deck to 4 inches and 2 inches. The barbettes should completely enclose the roller path and its substructure at least down to gun deck.

f. Unprotected Parts

The extension of armor being settled, it should be the object of the designer to reduce the unprotected areas as much as possible, notably those that project above the main deck. Wrecked masts, funnels, and cowls may become serious obstructions to the working of guns and to the general service, and demolished funnels may seriously check the draught (*Huascar*, at Punta Angamos).

Cowls should, therefore, be done away with, and funnels should not be higher than necessary to carry the smoke well clear of guns and conning tower.

5. Summary

The type of ship here proposed is but a modification of the *Connecticut* and *King Edward* classes. Provided the premises of this discussion are correct and the arguments sound, it was indeed to be expected that the result should agree essentially with the best recent designs, and more particularly with those which have not been restricted in displacement by financial considerations. The modifications proposed, although of great importance, are gradual in character, and follow as a natural consequence of recent changes in means and methods of warfare. The principal points are: —

Complete substitution of semi-heavy guns for the quick firers of secondary batteries, and consequent installation of all secondary guns in turrets, preferably twin turrets, placed on main deck.

Greater subdivision of engine power by triple screws.

Use of oil fuel by mixed combustion.

Greater metacentric height, and hence somewhat greater beam.

Abandonment of centre line bulkhead except where necessary between engine rooms.

Both inner bottom and wing passage bulkhead to be fitted along the sides. Greater distance of lateral bulkheads from side.

Wing spaces arranged as compensating tanks for righting the ship.

Side armor to maintain midship thickness and height to extreme end of magazines, where the transverse armor bulkheads should be placed.

Lighter protection of barbettes below main deck.

Only one armor deck.

6. Conclusion

We have arrived at the proposed type on basis of specified conditions. It has been shown how the qualities required to meet these conditions are interdependent, and how, therefore, only one solution can be the best, namely, that which is consistent with the organic relations existing between the different elements of the design. In the battleship so designed we may say that the qualities are harmoniously balanced, since no one is unduly favored at the expense of the others, and each is present in a sufficient measure. This solution has necessitated a displacement equal to that of the largest battleships now building. As shown in the paper, this is due to the fact that the

large ship, apart from its superiority due to higher speed, greater gun power, and better protection, is inherently superior to the smaller in point of nautical qualities, water-tight subdivision, economy of propulsion, and relative sea speed. These qualities cannot be attained in the same measure in a smaller ship, and since they are not subject to addition they cannot be compensated for by a greater number of units. The deficiencies will be greater the smaller the ship.

Let us imagine a squadron of smaller ships matched against one of larger ships of the same aggregate displacement. The superior speed and gun power will enable the larger ships, on one hand, to effect concentrations at close range on part of the enemy's force, and, on the other, to carry on the fight at distances where, although still able to destroy the weaker ships, they will themselves be practically immune against their artillery. We have here assumed a *general* inferiority of the smaller ship; if we assume a *partial* inferiority, involving a departure from harmonious design, the deficiency may not be apparent on all occasions, but in the course of time it is likely that the chances of war will bring the ship in a position where the quality in which it is deficient will be of great and even vital importance, and the defect may then prove fatal. The adoption of a smaller type of battleship than that necessary for the complete fulfillment of all the claims stated at the beginning of this paper must, therefore, be regarded as a retrogression.

On the other hand, it is admitted that great concentration on large units is undesirable on account of the dangers by submarine attack and ramming, for although the margin of safety is greater in the larger ship the inducement to such attack increases with size, and the risk of grounding also increases with size. This consideration puts an upper limit to size, namely, that found just sufficient for fulfillment of the claims. Hence *it would be unwise either to fall below or to exceed that displacement of the sea-going battleship found above to be necessary and sufficient for the due performance of its work.*

It must be borne in mind that as a basis for the design here proposed it has been assumed that the service of the sea-going battleship lies chiefly on the open sea, only exceptionally involving direct attack on fortified ports. This has necessitated the great claims to nautical qualities, and also, since the water-tight subdivision here proposed seems fairly adequate under these conditions, has justified the large displacement.

When we come to consider *coast war* in a narrow sense — harbor attack and defence, blockades, etc. — the case is different. Recent de-

velopments in submarine attack have rendered such work exceedingly dangerous, and this service is, moreover, accompanied by exceptional risks to large vessels by grounding and collision. Although the larger ship is better able to stand such damage, it must be admitted that smaller ships have here distinct advantages. Their smaller draught and greater maneuvering power make them more handy and less exposed to the dangers of grounding and collision, the smaller value of each unit makes it justifiable to run risks which should not be incurred with large ships, and their smaller power of resistance to submarine attack is probably more than outweighed by their greater number. Moreover, on account of reduced claims to nautical qualities — speed, radius of action, and living accommodations — small size may, in coast defence ships, be combined with great offensive and defensive power.

As a result of recent developments we have, therefore, to admit *a limitation in the use of the sea-going battleship and an increased necessity for the construction of special artillery vessels for coast war.* Such vessels, ranging from the *Arkansas* to the *Henri IV,* already exist, only the type must be chosen in accordance with the special requirements of the case, and developed to meet the changed conditions; but a study of this question lies outside the scope of this paper.

SOME NOTES ON LAURENT POLARISCOPE READINGS[1]

By GEORGE W. ROLFE and CHARLES FIELD, 3d

For many years the Laurent polariscope has been the common instrument in our chemical laboratories for the measurement of optical rotation, especially in the determination of specific rotatory powers, which are the constants of calculation in polarimetric analysis.

Till comparatively recently the results obtained with the Laurent polariscopes have been accepted as expressing rotations of the plane of polarization of the D ray, or ray of standard wave length. The light used in Laurent measurements, as is well known, is made by vaporizing common salt in a powerful Bunsen burner and filtering the rays through a section of potassium bichromate crystal.

The *saccharimetric* scale of the Laurent polariscope is based on the *specific rotation of quartz*, which was taken as 21.667 at the standard temperature. Later measurements of the specific rotation of quartz, even some made more than twenty years ago, give a higher value, 21.72 at 20°. As by common usage the 100 point of the Laurent saccharimeter is a fixed one, equivalent to the rotation value of 21.667, an attempt has been made to reconcile this value to the original definition by stating that this expresses the rotation of quartz at 6°. Obviously, this is merely a matter of definition, the scale being based on a fixed rotation, independently of whether this be the specific rotation of quartz or not.

The Laurent instrument is little used for saccharimetry in this country, the value of the specific rotation of quartz given by the instrument being chiefly of interest as a point of reference for the determination of the accuracy of its measurements as expressing angular rotations of the plane of polarization of the standard yellow ray.

In 1890[2] Lippich published a paper designed to prove, theoretically, that errors of 0.2 per cent. or more necessarily existed in Laurent

[1] Read at the Providence meeting of the American Chemical Society. Reprinted from the Journal of the American Chemical Society, August, 1904, **26**, No. 8.

[2] Zur Theorie der Halbschattenpolarimeter, Wien. Sitzungsber. (II), **99**, p. 695.

measurements. As confirmation of this, in the same paper, Lippich also published comparative measurements of the optical rotation of a standard quartz plate made on a Lippich polariscope and two of the Laurent type, the readings of which latter showed variations of forty-five to eighty-two seconds from those of the Lippich polariscope. It should be noted that in these experiments Lippich filtered the sodium light through both potassium bichromate and cupric chloride solutions, so that the light he used probably differed appreciably from that designed for the Laurent polariscope.

Landolt[1] has pointed out that the sodium light as usually employed in polariscope measurements is not homogeneous, but is made up of light of many wave lengths, most of them differing slightly from each other, but that such light can be considered as homogeneous light which has a wave length of the ray which is the resultant in intensity of all the rays emitted. This ray is termed the "*optical centre*"[2] of the light. In his work on optical rotation Landolt discusses the different optical centres of light used in polarimetric measurements, but does not consider exactly the kind of light used by Laurent instruments.

In most of the more recent accepted measurements of the specific rotation of quartz the light used has been the yellow rays of the two D lines of the spectrum, separated by spectroscopic methods, either from white light or from sodium flame.

For the Lippich polariscopes Lippich has designed a ray filter which practically absorbs all light except those rays adjacent to the D lines. This filter purifies the light of incandescent sodium chloride vapor so that its optical centre is practically that of the spectrally purified light. According to Landolt, who describes the preparation of the solutions in detail, it consists of a 10 cm. absorption cell filled with a 6 per cent. solution of potassium bichromate, and a 1.5 cm. cell filled with a specially prepared solution of uranyl sulphate.[3]

Consideration of many published rotation values obtained on Laurent polariscopes, as well as readings of the two instruments in the sugar laboratory of the Massachusetts Institute of Technology, has led us to believe that polariscopes of this type, if of French make, give readings which are concordant within one minute, at least, although about 0.2

[1] Optische Drehungsvermögen, p. 360.

[2] Optischer Schwerpunkt.

[3] Lippich, Ztschr. für Instr., 12, p. 340; Landolt, Optische Drehungsvermögen, p. 362.

per cent. lower than those obtained with the Lippich ray filter. As long ago as 1899 one of us published this opinion.[1]

Quite recently we have made two series of rotation measurements of two standard quartz plates on a Laurent polariscope, one set with the light designed to be used by the Laurent polariscope, sodium chloride light filtered through a section of bichromate crystal; the other set with sodium chloride light passed through a Lippich ray filter. The instrument used was a Laurent "large model," made about 1888 by Leon Laurent, of Paris.

The table gives the result of the measurements, as well as the saccharimetric readings of the two quartz plates, on the saccharimeters of the Institute laboratory, which are graduated in the standard Ventzke scale for use of Mohr flasks; and their readings also on a triple-shade saccharimeter of the United States Department of Agriculture, which latter readings were made by Dr. Wiley in 1898, and obviously are on the true cubic centimeter scale. (United States Custom House Standard.)

The saccharimetric readings of "Quartz A" plate show that, within a small error, it is a millimeter in thickness.[2] On this account it is interesting to note that the value given with the ordinary light used with the Laurent polariscope is practically that obtained for the specific rotation of quartz by the *earlier* investigators, while that given by the Lippich light closely approximates to the *modern* value.[3] The results, as a whole, have led us to believe that the difference in values obtained by the Lippich and Laurent measurements is not due to the imperfections of the Laurent instrument but to the kind of light used, at least up to the precision required in chemical laboratory measurements, or 0.1 per cent. of the values obtained.

The greater convenience of the Laurent polariscope, owing to its end-point adjustment being independent of the position of the polarizer for the regulation of the light intensity, as well as the advantage of the bichromate section over the Lippich ray filter, which absorbs a large percentage of light and soon deteriorates, owing to the oxidation of the uranium solution, makes the Laurent more advantageous than the Lip-

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[1] Journal American Chemical Society, 1899, **21**, R. 105.

[2] Landolt, Optische Drehungsvermögen, first edition, p. 162. The plate was always placed in the instruments in a definite axial position, but we have been unable to detect any difference in its readings in different positions.

[3] Landolt, Optische Drehungsvermögen, p. 130.

pich for general laboratory measurements. Our results show that Laurent measurements can be converted to the standard of spectrally purified light[1] by increasing their value 0.2 per cent. The tabulated light factors calculated from the different rotation and saccharimetric values will, it is hoped, explain some of the different values which are given indiscriminately and, in fact, without proper explanation in the various publications dealing with optical rotation.

It may be unnecessary to point out that Rimbach,[2] Landolt,[3] and others have shown that the light factor of a quartz-wedge saccharimeter may vary with the nature of the substance measured. This is on account of the difference in the rotary dispersion of quartz and the solution measured, the result being that all the rays of the spectrum whose planes are rotated by the solution are not restored exactly to their original angular positions by a section of oppositely rotating quartz of one definite thickness. Hence no position of the quartz compensation wedges will exactly restore the original light effect of the end-point when the solution is placed in the instrument, and a more or less parti-colored field is given in shadow saccharimeters. If the dispersion difference is slight, this can be obviated and an evenly tinted field obtained by absorbing the rays of the blue end of the spectrum by means of a ray filter of bichromate solution, or somewhat less effectively, but more conveniently, by means of a piece of brown (carbon) tinted glass. The ray filter, however, in the case of the quartz-wedge saccharimeter, merely assists in obtaining a more precise end-point. The light factor, as determined by a solution of commercial glucose, for instance, will differ appreciably from that obtained with quartz. Even cane-sugar solutions differ sufficiently from quartz in rotary dispersion to give light factors of slightly different value.

Hence it is imperative, in stating that the light factor of a saccharimeter is a certain value, that reference should be made (1) to the exact nature of the light used in the rotation readings; (2) the saccharimetric standard of the scale of the quartz-wedge instrument; (3) the nature of the substance measured; and (4), obviously, the temperature at which the comparisons are made. It would seem as if these conditions of measurement ought to be well known, but they are singularly ignored

[1] This is assuming, on Landolt's authority, that the sodium light purified by the Lippich ray filter is practically identical in wave length with the spectrally purified light.

[2] Ber. d. chem. Ges., **27**, p. 2282.

[3] *Ibid.*, **21**, p. 191.

in statements in publications on the subject to the confusion of most readers.

READINGS AT 20°

	(1) Saccharimetric readings, original Ventzke scale.	(2) Saccharimetric readings, true cc. scale.	(3) Laurent readings, original light.	(4) Laurent readings, Lippich ray filter.
Quartz A	62.66	62.45	21.667	21.719
Quartz D	96.02	95.77	33.200	33.284

CALCULATED LIGHT FACTORS

	From (1) and (3).	From (1) and (4).	From (2) and (3).	From (2) and (4).
Quartz A	0.3458	0.3466	0.3469	0.3478
Quartz D	0.3458	0.3466	0.3467	0.3475

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QUARTZ-PLATE READINGS IN SACCHARIMETRY

By GEORGE W. ROLFE

It has long been noticed by the writer that comparisons of quartz-plate readings made on the United States standard saccharimeter, scaled for use with "true" cubic centimeter flasks, with those taken on the Ventzke standard instrument did not give the constant ratio 1 : 1.0023 at all parts of the scale. For instance, referring to the tabulated readings of the preceding paper (p. 293), the ratio of the readings of the D plate is 1 : 1.0026, which is a close approximation to the ratio of the volume of the true cubic centimeter to that of the Mohr flask, but the ratio of the corresponding values of the A plate is 1 : 1.0034. This discrepancy is not accounted for by experimental error, as many readings on different saccharimeters are remarkably concordant.

Sawyer, in his paper on variations in standards of Ventzke saccharimeters (*Journal American Chemical Society*, **26**, p. 990), has published a comparative table of such readings, in which are included some made by the writer. These will show a remarkable concordance in ratios of readings taken at the *same* corresponding parts of the scale on the two classes of saccharimeters, but show the same variation between the 100 and 50 points. It will suffice here to consider the readings of four plates on the two Institute saccharimeters, Schmidt and Hänsch, No. 2880, and Scheibler (half shade), No. 624, and the readings made by Dr. Wiley in 1898 on the triple-shade United States standard saccharimeter, No. 3923. These readings and their ratios are given in the following table: —

TABLE A — Comparison of Quartz-Plate Readings on United States Ventzke Standard Saccharimeters

	(1) No. 3923.	(2) No. 2880.	(3) No. 624.	Ratio (1) : (2)	Ratio (1) : (3)
Quartz A	62.45	62.66	62.66	1 : 1.0034	1 : 1.0034
Quartz B	55.11	55.32	55.28	1 : 1.0038	1 : 1.0031
Quartz D	95.77	96.02	95.96	1 : 1.0026	1 : 1.0022
Quartz E	99.84	100.06	100.08	1 : 1.0023	1 : 1.0024

The ratios of quartz readings near the 100 point closely approximate to that expressing the relative volumes of the true and Mohr flasks, as would be expected. Why is the ratio larger in the middle of the scale? This was long a puzzle to the writer till about a year ago, when he came across a statement in von Lippmann's "Chemie der Zuckerarten" (p. 1363, third edition), to the effect that modern saccharimeters are graduated to give correct percentages of sugar at all concentrations, main points (*Hauptpunkten*) of the scale being standardized by aliquot parts of the normal weight of cane sugar.

As is well known, the specific rotation of sucrose in aqueous solution is not strictly a constant at all concentrations used in saccharimetry. Consequently the readings of sugar solutions of different concentrations are not strictly proportional to the thickness of the section of compensating quartz if the saccharimeter is graduated so that any reading n represents a position of the wedge corresponding to $n/100$ of the thickness of a section of quartz compensating at the 100 point. In other words, a quartz-wedge saccharimeter whose wedges are perfect planes and whose scale divisions are equal does not give an exact reading of the percentage of sugar at all parts of the scale.

The error is a small one, and has its maximum in the middle of the scale, where the instrument underreads .08 of a division, or 0.16 per cent. of the numerical value. As long ago as 1878 Schmitz (*Zeit. Ver. Rüb. zuck. Ind.*, **28**, p. 65) made a table of corrections for use with quartz-wedge saccharimeters. Applying Schmitz's correction for the middle of the scale, the ratio of the readings of the A and C plates on the United States and Ventzke standard saccharimeters, assuming the United States standard instrument to be graduated for reading correct sugar percentages at all concentrations, would be, theoretically, 1 : 1.0039. This is within the error of observation of the actual readings, the mean variation corresponding to about 0.025 of a scale division.

Hence it seems correct to infer that the United States standard instruments have wedge surfaces which are slightly *curved* to enable the instrument to give correct readings of sugar percentage of (pure) aqueous sugar solutions at all concentrations less than normal which are measurable on the saccharimeter. Presumably, also, from von Lippmann's statement, since he also asserts, as does Landolt, that the Mohr standard is the only correct one in saccharimetry, there are correspondingly graduated instruments for Mohr flasks.

The question might well be raised whether, in general, greater accuracy in commercial saccharimetry is gained by such graduation, since the "non-sugars" in solutions of commercial products, especially mineral matter, might prove far more disturbing of the specific rotation of sucrose than the water present; and such error is still quite uncontrolled.

Owing to its great convenience and precision the quartz-wedge saccharimeter is a most useful instrument for measuring *rotations* of many optically active substances, particularly hydrolyzed starch products, the rotations of which, in terms of standard yellow light, can be accurately determined by multiplying the readings by the appropriate light factor. Indeed, where no rotary polariscope is available the quartz-wedge saccharimeter can be substituted in all cases if sodium light is used as an illuminant, since dispersive disturbances are eliminated, and for all substances the factor becomes practically that for quartz with compound light.

This greatly extends the usefulness of the saccharimeter for general laboratory work. If, however, the instrument is graduated according to Schmitz's corrections, not only in testing commercial products is the gain in saccharimetric efficiency questionable, but such graduation is decidedly disadvantageous for general rotation work, as the light factor is not constant for all parts of the scale, and consequently the calculation is complicated

Through the courtesy of Dr. Wiley the writer had the opportunity to use a set of the "International" quartz plates standardized by the German Bureau of Standards (*Physikalisch-technische Reichsanstalt*). Four of these plates were read on the Schmidt and Hänsch saccharimeter, No. 2880, the Laurent "A" polariscope of the sugar laboratory of the Massachusetts Institute of Technology (p. 291), and a large Landolt-Lippich polariscope belonging to the Physical Department of the Institute. This Landolt-Lippich instrument is one of the most advanced type, made for measurements of the highest precision now attempted, and reading to .001° by means of filar micrometers.

The Laurent polariscope was used with the ordinary sodium light and bichromate plate as designed for the instrument. The sodium light for the Landolt-Lippich polariscope was passed through a Lippich ray filter.

The numerous readings taken are briefly summarized in the following table (B). In general, they show (1) that the saccharimeter No. 2880 has a constant light factor throughout its scale; (2) a close

agreement with the factors obtained in the previous paper of the author and Charles Field, 3d.

TABLE B — COMPARISON OF READINGS OF QUARTZ PLATES WITH THEIR ROTATION VALUES OBTAINED ON LAURENT AND LANDOLT–LIPPICH POLARISCOPES AND THE RESULTING LIGHT FACTORS ($t = 20°$)

Plate No.	(1) Saccharimetric reading.	(2) Laurent reading.	(3) Landolt–Lippich reading.	Light Factors.	
				From (1) and (2).	From (1) and (3).
299	97.03	33.552°	33.628°	.34579	.34656
1399	76.32	26.372°	26.436°	.34552	.34636
2899	49.71	17.195°	17.231°	.34593	.34665
3699	24.85	8.600°	8.613°	.34607	.34655
				(Av. .34583)	(Av. .34655)

In the author's experience the Landolt-Lippich polarizer is not as satisfactory for instruments for general laboratory use as the Laurent, because the former requires that all extraneous light be rigidly excluded and seems much more sensitive to small variations in intensity of the sodium flame than does the Laurent. In short, the Landolt-Lippich gives discordant readings under conditions when the Laurent readings will be constant within the mean error of observation. Furthermore, the Lippich polarizer is apparently affected by any marked temperature change, the direct cause seeming to be due to the effect on the metal of the mountings of the prisms. This manifests itself in change in zero error.

Only under constant conditions of temperature and light intensity, and with a rigid exclusion of all extraneous light, can good results be obtained with the Lippich polariscope.

It should further be noted that the practical identity of the wave length of the Lippich filtered sodium light with spectrally purified light is assumed on Landolt's authority ("Optische Drehungsvermögen," p. 362). Recent measurements of these plates with spectrally purified sodium light, which will be described in a paper by H. E. Sawyer and the writer, do not completely confirm this identity.

Note on a Simple Type of Sodium Lamp for the Polariscope.[1] — Many forms of sodium light lamps have been devised. Most of them

[1] From The Polariscope in the Chemical Laboratory. New York: Macmillan, 1905.

use ordinary table salt, which is best adapted for the purpose, the other common salts of sodium not volatilizing so readily, and consequently giving less intense light. Sodium carbonate works reasonably well, but causticizes to a considerable extent, forming a corrosive liquid, which drops down and fouls the apparatus. Sodium bromide is said to produce a more intense light than the chloride, but gives off bromine vapors, which are apt to injure the polariscope. Landolt uses cylinders of salt, which are fused on small forms made of nickel wire netting. Wiley has devised a clockwork lamp by which the salt is fed into a Bunsen flame from opposite sides by means of two slowly revolving wheels of platinum gauze, which dip into dishes holding a salt solution.

The ordinary type of lamp consists of a Bunsen burner so adjusted as to burn with as strong an air blast as possible, this being a requisite for any lamp giving intense light. The salt is exposed to the flame in a platinum or nickel-gauze spoon, which is heated in the mantle just outside the luminous cone — the hottest part of the flame. The intensely bright yellow sodium vapor is then carried by the blast well above the blue cone of the flame, the light of which latter should be cut out of the polariscope field by a diaphragm attached to the lamp. A mixture of table salt with sodium phosphate, as recommended by Dupont, fuses upon the gauze, and does not decrepitate as salt does alone. A mixture of these powdered salts made into a paste with a little glycerine has been found very convenient for applying to the gauze with a small platinum spatula.

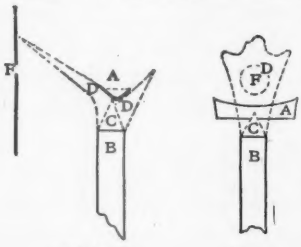

FIG. 1. — SIMPLE TYPE OF SODIUM LAMP

A, boat; *B*, burner; *C*, blue flame; *D*, yellow flame; *F*, diaphragm-opening.

Quite recently the author has adopted a simple type of sodium lamp, which has proved by far the most convenient and efficient (Figure 1). A shallow boat, made by folding up a rectangular piece of platinum foil and welding together the ends by hammering at a red heat, is used to hold the salt. The boat is of such shape as to spread the flame of a Tirrill burner, which impinges against the polished platinum after the manner of a bat's-wing flame. The salt that is liquefied creeps up the sides of the boat and is vaporized in the flame, giving a very brilliant and steady light, which lasts for fifteen minutes or more without renewing the salt.

The flame shoots off obliquely, thus exposing more light surface in the axis of vision. From time to time lumps of salt (which have previously been fused) are added till the boat is again filled with liquid.

The diagrams explain the apparatus, the exact adjustment of the position of the platinum boat being easily determined by experiment.

A more elaborate but somewhat more efficient boat for holding the salt is shown in Figure 2. A piece of platinum foil is folded double in such a way as to make a double-bottomed boat, the edges of the folded sheet making a narrow slit along one edge of the boat. The inner bottom is perforated. In this form the liquefied salt rises by its capillarity to the mouth of the slit, and is taken by the strong blast of the lamp up into the flame in a brilliant sheet. Such an arrangement has given a constant light for an hour without replenishing.

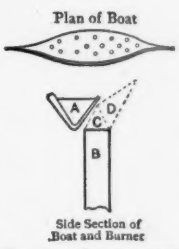

FIG. 2. — LAMP WITH DOUBLE-BOTTOMED BOAT

Lettering as in Fig. 1.

The platinum boats must not be too large, or the mass of metal chills the flame and reduces the intensity of the light appreciably. It may be needless to add also that the burner must be working with as strong an air blast as possible.

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THE PRODUCTS OF THE DISTILLATION OF PINE WOOD

By WILLIAM H. WALKER, ELMER W. WIGGINS, AND EDWARD C. SMITH

Introduction. — In order to supply the ever increasing demand for spirits of turpentine and rosin, there must be invaded annually somewhat over eight hundred thousand acres of virgin forest. It is not long ago that the Southern forests of long leaf pine (*Pinus palustris*) were considered practically inexhaustible; now the centre of the turpentine industry has passed from North Carolina, where it had its origin, to Florida and the other Gulf States. Although the United States Bureau of Forestry has done much to improve the antiquated methods generally used in tapping the trees and gathering the resin, the waste and wanton destruction of the forests which still obtains is such that the life of the industry is limited to a few decades, unless greater economy is practiced by the individual producer. Within the last three years the price of rosin has almost doubled, while the price of turpentine has steadily advanced; at the present rate of increase the next five years will see the prices of both double again.

Under the name "lightwood" there is recognized throughout the turpentine district of the South such portions of the long leaf pine as have either during some period of growth or after the death of the tree become saturated with resins. The three most common varieties of lightwood are, trees that have died standing and in which the resins have accumulated in the lower part of the trunk, stumps and roots of trees which in a few years become saturated with resins, and those portions of trees which have been "boxed" or "faced" for the production of turpentine during the life of the tree. This wood, contrary to what is implied by the name, is very hard, dense (sp. gr. 1.075), and brittle, and without value at present except for fuel.

The first attempt to recover the large amount of turpentine and rosin contained in this waste wood was made by James Stanley in 1872. Owing to the then existing low prices of these materials and the small yield obtained, the enterprise ultimately failed. The enhanced value of naval stores in general which has obtained during the last three years

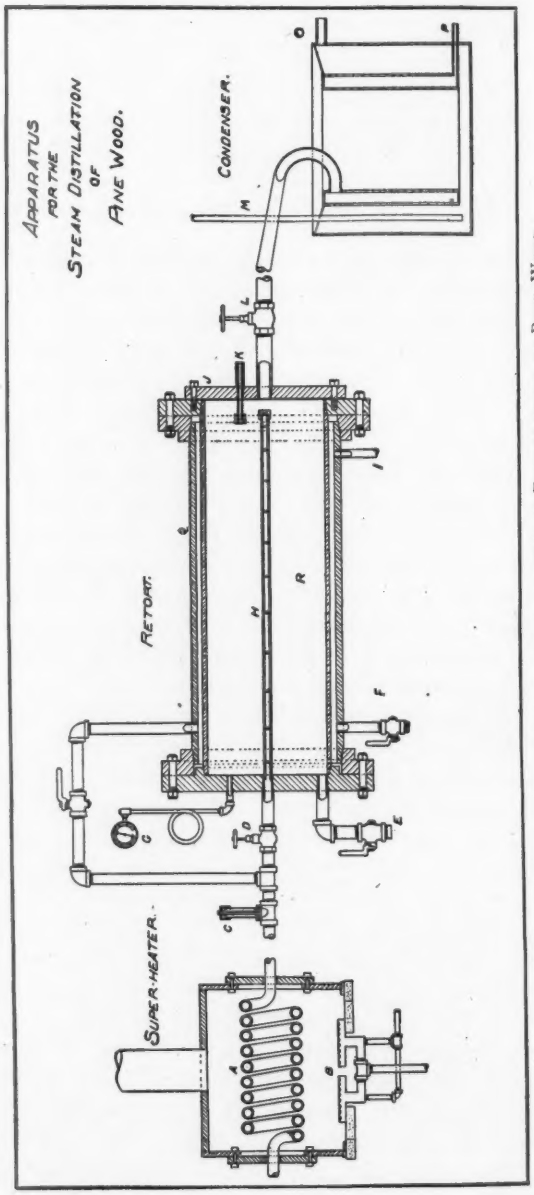

FIG. 1.—PLAN OF THE APPARATUS FOR THE STEAM DISTILLATION OF PINE WOOD

has, however, lent a powerful stimulus to investigation having in view the better utilization of this waste material. A large number of patents of doubtful validity have appeared relating to the distillation of pine wood both with and without the use of superheated steam, but there have been published no data regarding the temperatures employed or the products obtained. It was thought worth while, therefore, to carry on a series of experiments on the distillation of waste pine wood in which the relation of temperature to product would be studied, the various products investigated, and the percentage yield of each estimated.

The Apparatus. — The apparatus employed in this investigation consisted in a superheater, a retort, and a condensing system, as shown in the accompanying drawing (Figure 1).

The Superheater consisted of a coil of $\frac{3}{4}$-inch wrought-iron pipe heated in a furnace by the gas burners shown at *B*. The burners are supplied with a blast of air through the small pipes. Steam from the mains is led into the superheater, and is conducted into the retort by a $\frac{3}{4}$-inch wrought-iron pipe.

The Retort was made of a 12-inch wrought-iron pipe inside a 14-inch pipe, which served as a jacket. These pipes were fitted with heavy cast-iron flanges bolted together. The temperature of the superheated steam was indicated by a thermometer placed in the tube *C*, fusible metal being placed in the bottom to ensure good conduction of heat. The steam main branched, one pipe taking steam into the jacket of the retort marked *Q*. Exhaust steam escapes from the jacket through the pipe *I*, which is provided with a valve (not shown) to control the rate of the outflow. Condensed steam is drawn off at *F*. The valve *D* on the other branch pipe controls the admission of steam to the retort *R*. The steam is distributed in the retort by the pipe *H*. A thermometer inserted at *K* indicates the temperature within the retort, while the pressure is registered by the gauge *G*. *J* is a removable head, which is taken off to remove and insert the charge. Any rosin which may collect during the run is drawn off at *E*. The outlet is 1-inch wrought-iron pipe provided with a valve at *L* to control the rate at which the vapors enter the condenser.

The Condenser was made of sheet copper in the form of a hollow cylinder set in a cooling tank. Cooling water is run in through the pipe *M* and overflows at *O*. Condensed steam and oil are drawn off at *P*.

The arrangement of the apparatus is shown by the accompanying photograph (Figure 2).

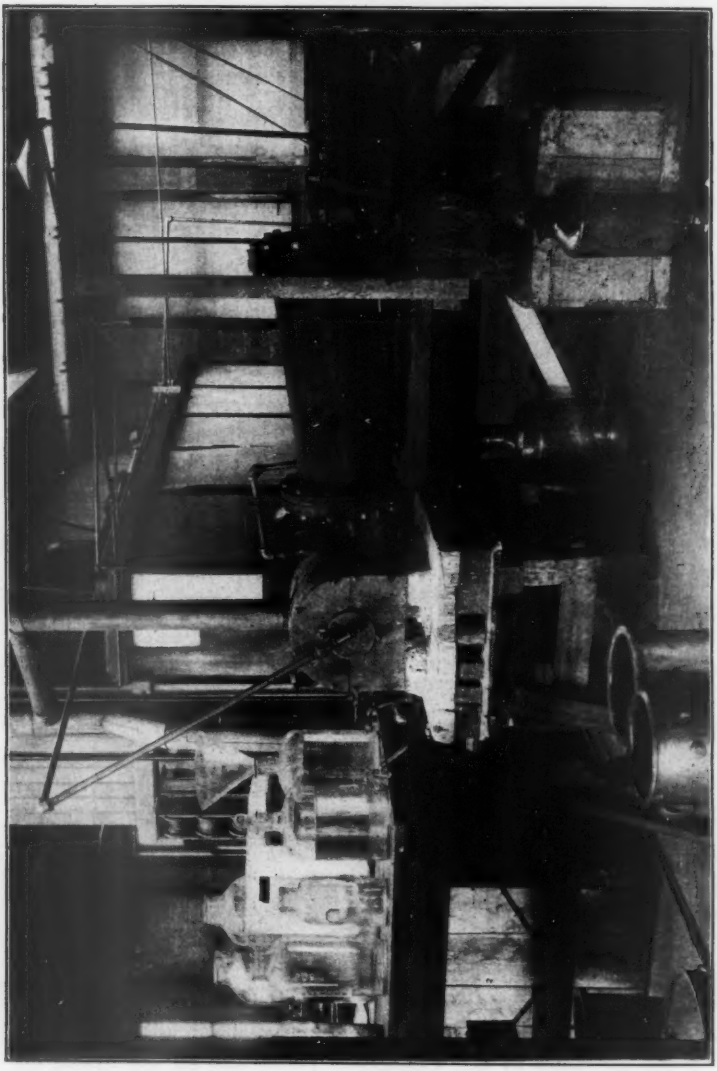

FIG. 2.—THE APPARATUS FOR THE STEAM DISTILLATION OF PINE WOOD AS SET UP IN THE LABORATORY

The Experiments. — The wood used in the first runs was a mixture of stumps and roots, much of which had been more or less charred by forest fires. This was cut into small pieces, but, unfortunately, not very well mixed, the results of these runs indicating that the resin was not uniformly distributed. In the later runs the wood was very carefully sampled and uniformity of the raw material assured.

The conditions governing these first six runs were as follows: Steam direct from the main but without superheat was led into the retort for two hours. The pressure in the retort was regulated by the exit valve, and was held at about 40 pounds. During this period most of the rosin and about two-thirds of the oil were obtained. At the end of this time action upon the wood had apparently ceased, and the entering steam was superheated to from 375° C. to 400° C. This temperature was maintained for two hours longer. A large amount of gas having a strong empyreumatic odor and burning with a luminous flame was given off during this part of the run; toward the end it burned with a pale blue flame, indicating only carbon monoxide. Runs VII to X, inclusive, were made by passing in from the first, steam superheated to 180° C., and continuing at this temperature for two hours. The products obtained did not differ much from those of the previous runs, but the yield seemed to be improved. The superheat was then increased to 400° C. and maintained for four hours. Runs XII and XIII were much the same, except that the superheat was commenced at 200° C.

Runs XIV and XV were made as those immediately preceding, but instead of lightwood stumps and roots, railroad ties cut from the heartwood of moderately young trees were used. The results on this wood were disappointing, as it was found to vary greatly in its content of resin.

Tabulation of Results. — The crude oil as it came from the condenser was so contaminated with rosin and so difficult to separate from the water, that before determining the yield it was in each case once distilled with steam at very little above atmospheric pressure. The distillation process was without difficulty divided into two parts, the first furnishing a light, almost colorless oil, and the second distilling much more slowly and yielding a thick, yellow oil.

The results are as follows: —

TABLE I

RUNS I TO VI

Run.	Initial temperature.	Clear oil.	Yellow oil.	Rosin.
		Per cent.	Per cent.	Per cent.
I	144° C.	1.03	1.47	4.7
II	150° C.	1.05	*	2.25
IV	160° C.	1.84	0.5	3.46
V	157° C.	1.80	*	1.63
VI	160° C.	2.26	1.25	7.65
RUNS VII TO X				
VII	170° C.	3.00	0.49	6.35
VIII	173° C.	3.47	0.54	5.47
IX	180° C.	3.02	0.47	4.30
X	175° C.	3.12	0.82	5.40
RUNS XII AND XIII				
XII	220° C.	2.60	0.70	*
XIII	190° C.	2.40	0.58	*
RUNS XIV AND XV				
XIV	170° C.	0.79	0.69	0.0
XV	175° C.	0.27	0.14	0.0

* Not determined.

The following table gives the average results from the first three sets of runs, and shows the results obtained from each manner of heating.

TABLE II — AVERAGE RESULTS

Runs.	Initial temperature.	Clear oil.	Yellow oil.	Rosin.
		Per cent.	Per cent.	Per cent.
I–VI	155° C.	1.96	0.81	3.97
VII–X	174° C.	3.15	0.58	5.38
XII–XIII	200° C.	2.50	0.64	2.80

The conclusions drawn from the results are: —

1. That the *optimum* conditions for both turpentine and rosin are an initial temperature of 175° C., followed by steam superheated to about 400°. Not only is the yield of turpentine improved, but the amount of rosin is increased by maintaining this temperature for two hours. If the temperature is much below 170° C. the oil comes over slowly, and will ultimately cease to distill unless the temperature is raised. If the temperature is run above 200° C. the yield is not improved; the turpentine is discolored and has a burnt odor. The yield of rosin appears to be decreased with the higher heat, due to the fact that it decomposes and distills over with the turpentine.

2. That the oils obtained from the different runs are identical, having the same properties, except when excessively high temperature is used, when oil has a burnt odor.

3. That the heartwood is of little value for producing turpentine as compared with stump wood. The oil obtained was of poor color, disagreeable odor, and small yield.

Properties of the Clear Oil. — The turpentine, or clear oil, obtained from the steam distillation gave, when fractionated, 80 per cent. distilling below 163° C. and over 90 per cent. below 175° C. The major portion of this oil is probably pinene, $C_{10}H_{16}$. The standard set for commercial turpentine is that 85 per cent. shall distill over below 163° C.

In specific gravity this oil averages 0.865–0.867, agreeing exactly with that of commercial turpentine.

In color it compares favorably with that of the commercial article, some samples being water white, others having a slight yellowish tinge.

When examined with a polariscope it showed a specific rotatory power of $+28.7°$. This test seems of little importance from the fact that three different samples of ordinary turpentine, examined at the same time, showed specific rotatory values from $-4°$ to $+13°$.

In odor the oil differed markedly from that of ordinary turpentine, resembling the wood from which it was made. It was more ethereal, and therefore more agreeable and less pungent than that of the ordinary turpentine. Since the principal test made upon turpentine by the government and trade inspectors is through the odor, this material would no doubt immediately be rejected. The users of turpentine have become accustomed to the ordinary article, and hence would be prejudiced against this oil.

Tests for free acid by titration with $N/_2$ alcoholic potash showed the absence of acids in any appreciable quantity. The values found were .0077 per cent. and .0079 per cent.

Upon saponification with alcoholic potash and titration with $N/_2$ HCl, about 7 per cent. of esters was found, calculated as bornyl acetate. A sample of commercial turpentine tested at the same time showed 1.44 per cent. of esters.

An attempt to remove the color and odor from this turpentine was made, using dilute potassium permanganate solution. About 92.8 per cent. of a water white oil was obtained having no disagreeable odor.

Evaporation tests were made upon two samples of this clear oil, or "wood turpentine," to determine the amount of volatile matter and amount of residue present. The test consisted of putting about .2 gram oil upon a watch glass and allowing it to evaporate in the air. The weight of the residue was determined and the percentage of residue and of volatile matter calculated.

TABLE III

Sample.	Volatile matter.	Residue.
	Per cent.	Per cent.
Clear oil, No. 1	98.98	1.02
Clear oil, No. 2	99.29	0.71

Two tests were made with commercial turpentine at the same time, with the following results: —

TABLE IV

Sample.	Volatile matter.	Residue.
	Per cent.	Per cent.
W. and H., No. 1	99.6	0.4
Prentiss, No. 1	98.8	1.2

So far as volatility is concerned these oils compare favorably with the commercial samples examined.

Properties of the Yellow Oil. — The yellow oil obtained from the distillation with steam was submitted to a fractional distillation. Almost the entire amount boiled between 200 and 214° C. The fraction 209–211 constituted fully 60 per cent. of the whole, and was apparently

a homogeneous substance. When the oil was diluted with alcohol, saturated with dry HCl gas, and cooled it solidified to a mass of white crystals melting at 50° C. Further work will be done upon it, but the indications are that it is a terpineol.

Treatment of the Rosin. — A quantity of crude rosin was heated for three-quarters of an hour at a temperature of 150° C. to drive off the moisture. Upon cooling it solidified to a hard mass with clear, vitreous fracture, but it was almost black in color, and opaque except in thin pieces. Another portion, heated for a shorter time at 140° C., was lighter in color, but was cloudy and had a less glassy fracture.

Since the rosin produced by the steam distillation seemed to be of poor grade, and consequently of little commercial value, it was subjected to dry distillation in a copper still. It was hoped that rosin spirit and rosin oil might be obtained having a greater market value than the rosin itself.

The products resembled closely those obtained from the distillation of ordinary rosin, and were as follows. The boiling point ran from 330° C. to somewhat above 360° C. : —

TABLE V

Products.	Weight.	Per cent. yield.	Specific gravity.
	Grams.		
Acid liquor	87	15.34	. .
Rosin spirit	73	4.49	0.930
Rosin oil	430	26.47	0.990
Blue oil	291	17.91	0.994
Green oil	270	16.62	1.030
Tar	75	4.62	. .

Dry Distillation of the Wood. — After the treatment with superheated steam the wood was subjected to destructive distillation. For this purpose a cast-iron retort was substituted for the superheating coil in the furnace and a direct coil condenser attached. The temperature in the interior of the retort was measured by a thermoelectric pyrometer. The gas evolved burned with a clear, luminous flame, and was used as part of the fuel for the furnace.

The first run was made at a temperature of 300° C., and continued for two hours. The pyroligneous acid and tar produced was of the

well-known type, but the charcoal was especially dense and hard, having a bright, metallic lustre.

In the remaining runs the retort was heated slowly to 175° C., and held there for one hour. Then the temperature was raised to somewhat over 300° C. The results obtained were as follows, the products being the same in quality as in the first run.

TABLE VI

Run.	Weight of wood.	Gas.	Crude product.	Tar.	50 per cent. acid.	Oil.	Charcoal.
	Kilogram.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
I	2.2	43.9	34.2	19.5	1.18	3.0	23.9
II	2.0	28.7	46.9	25.9	1.70	2.5	24.5
III	2.0	25.9	39.6	19.8	1.32	2.6	34.5
IV	2.0	24.1	51.4	26.8	1.86	3.6	23.3

From this we conclude that high and rapid heating produces larger amounts of gas, while comparatively low temperatures at the beginning cause increase in the amount of tar and acid.

In commercial practice the acid liquor from the redistillation would be run into milk of lime. From this the alcohols and acetone would be distilled, and the residue, evaporated to dryness, would yield gray acetate of lime. The creosote oil finds a market as a wood preservative.

Distillation of the Tar. — The tar, after the acid and light oil were driven off, was subjected to a fractional distillation in a copper still. An oil was first driven over which was originally light-colored, but later absorbed oxygen from the air and turned dark. It showed a violet blue fluorescence. A little acid water was also carried over. The oil was treated with NaOH to remove cresols, which, upon acidifying the alkaline solution, were separated.

Weight of tar treated	360 grams.
Weight of acid and water	24 grams.
Weight of oils	140 grams.
Weight of creosote in oils	32 grams.
Weight of solid residue in still	196 grams.

The residue upon cooling was hard, showing a black, glassy fracture. This product is known as "pitch" in the naval store industry.

The following table gives the yields of the different products per cord as calculated from the average results obtained from Runs VII

to X by the steam distillation and Runs II to IV by dry distillation. These runs were selected since they seem to have been conducted on the most productive basis.

Yield per Cord. — Estimated weight of a cord of lightwood, 6,000 pounds.

Product	Amount	Yield Per Cent.
From steam distillation: —		
Turpentine	24.9 gallons	3.0
Yellow oil	4.4 gallons	0.56
Rosin	318 pounds	5.3
From distillation of rosin: —		
Rosin spirit	2.5 gallons	0.3
Rosin oil	10.9 gallons	1.5
Blue oil	7.25 gallons	1.0
Green oil	5.6 gallons	0.8
Pitch	12 pounds	0.2
From dry distillation of wood: —		
Gray acetate of lime	46.2 pounds	——
Light oil	18.4 gallons	2.34
Charcoal	1,050 pounds	17.5
Gas	3,750 cubic feet	2.0
Wood tar	1,217 pounds	20.28
From distillation of wood tar: —		
Creosote oil (15 per cent.)	306 pounds	5.1
Wood pitch	516 pounds	8.6
From creosote oil: —		
Creosote	45.9 pounds	0.76

Conclusions. — The results of these experiments indicate that a turpentine can be obtained from lightwood by steam distillation, and that this turpentine is in every way the equal of the present commercial article, with the exception of its slightly different odor. This one point, however, may be sufficient to prevent its meeting with an extensive market for some time, at least. This will be due to the prejudice that is always shown by the public against any new article of commerce that varies even in a trifling way from the one commonly used.

We believe that we have demonstrated that there is in the waste trunks, stumps, and roots of the long leaf pine existing in great quantity throughout the Southern states a supply of raw material for the manufacture of naval stores hitherto unappreciated, and which is destined to play an important rôle in the economy of the South.

Laboratory of Industrial Chemistry,
May, 1905.

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BOOK REVIEWS

The Copper Mines of Lake Superior[1]

This book is the result of a sojourn of three weeks in the copper district. From notes taken and observations made at that time, coupled with information obtained from the literature, this little book has been evolved.

Its size is in no way commensurate with the magnitude of the operations, which yield to the world over 15 per cent. of its total copper supply. In fact, in the author's words, it is "all too short to do justice to so wide a subject, but it will . . . convey to those who have never been to these splendid mines some idea of their exploitation, their geological conditions, and the treatment of their output." From start to finish the reader's interest is held by the author's characteristic narrative style, which weaves in dull facts and statistical figures with the story of the discovery and working of these great mines.

From an introduction of statistics and general facts the reader is led through a short outline of the geology and a history of the discovery and development of the more important mines up to the present day. It is hard to believe that only sixty years ago modern operations began, that the record of the great Calumet and Hecla has been made in only forty years, and that none of the present producing mines were in existence fifty years ago.

After the history the author describes the methods of breaking the ore and raising it to the surface under the different conditions which prevail in the different mines. More particularly in these chapters the book is characterized by the insertion of many little "tricks of the trade," which cannot but help to be useful to readers who are engaged in actual mining.

A digression is made to devote a chapter to the story of many of the large masses of native copper which have been found from time to time, and another chapter to the methods of prospecting and opening up of some of the more recent mines.

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[1] The Copper Mines of Lake Superior. By T. A. Rickard. New York: The Engineering and Mining Journal, 1905. 164 pp., ill., 8vo.

Back to the main line of thought again, one chapter serves to give a comprehensive idea of the milling methods which are necessary to eliminate the large amount of waste rock from the "mineral" or valuable particles of native copper; then a chapter on smelting practice tells of the melting and refining of this "mineral," which process yields the copper in the merchant form to go to the market.

Looking back over the whole book the reader realizes how difficult it must be for an author to keep his story within bounds when dealing with such a fertile subject as this, and that many things necessarily have to be omitted. There is one gap, however, which impresses one who has traveled in the copper country, and this is the absence of a description of the enormous hoisting machinery which raises such quantities of ore from the depths of the earth. Another gap, which is not unexpected, however, is due to lack of information regarding the mining methods in the Calumet and Hecla and the Tamarack mines. The author regrets this, and explains that it is through no fault of his, but is on account of the inflexible rule of the managements of these two mines.

The book cannot but be of value to all classes — to the general reader who is looking for information presented in an interesting manner; to the mining man who is so far removed from Lake Superior that he may never need to come in actual contact with these mines, but who should, nevertheless, have a good idea of the practice which they illustrate; to the man who has had an intimate connection but is now at such a distance that he will welcome this book, like a letter from home, which tells him of the progress made since his departure; and, finally, to the man who is on the spot, and who will be glad to learn how his methods impress an outsider.

C. E. Locke.

Liquid Fuel[1]

This report gives in great detail the results obtained in seventeen coal and sixty-nine oil burning tests under an experimental boiler. The type of boiler chosen was of the water-tube variety of American design,

[1] Report of the United States Naval Liquid Fuel Board of Tests conducted on the Hohenstein Water-Tube Boiler, showing the relative evaporative efficiencies of coal and liquid fuel under forced and natural draft. By John R. Edmands, Wythe M. Parks, and Frank H. Bailey. Washington, 1904. 450 pp., large 8vo.

built by the Oil City Boiler Works, which company was willing to expend fifty to one hundred thousand dollars to see if it would be worth while to extend their plant for its manufacture. While improvements have been made in guns and armor and in their disposition, little change has taken place in the boilers — probably the most important part of the ship. All the data recorded were taken by persons connected with the Navy Department, and no effort was made to secure results that would eclipse other records, but rather to obtain results that would show what might be done in actual service. Particular attention was paid to having the results obtained absolutely reliable. It being out of the question to test all the oil burners that were offered, a few representatives from each class were chosen.

Oil burners were divided into five classes: —

I. The Drooling burner, a modification of the Jenssen slit burner.

II. The Atomizer burner, similar to the above, except that the oil duct projects over the steam duct.

III. The Chamber burner, a type of the one below, except that the oil and steam have an opportunity to mix within a chamber in the burner before being projected out into the furnace.

IV. The Injector burner, similar to a steam injector for water.

V. The Projector burner, in which steam escapes around a central tube of oil.

All these burners may be modified in four different ways: —

A. Straight shot burners, consisting of two round, straight pipes side by side.

B. Long slot burners, in which the round pipes are replaced by flat tubes.

C. Fan-tailed burners, which have their delivery tube at right angles to those of *A* and *B*, so that the oil is delivered vertically upwards instead of horizontally.

D. Rose burners, consisting of *A* or *B* arranged in a circle.

Besides burners, furnaces are discussed, also accessory apparatus, such as air compressors, pressure regulators, etc.

In addition to their own tests, reports of the voyages of the steamers *Mariposa*, *Nevadan*, *Nebraskan*, *Alameda*, *Tebe*, and *City of Everett*, burning oil fuel, are included; also tables showing the world's production of coal and oil and that of the United States. It is to be noticed that they state that less than 3 per cent. of the world's production of fuel can possibly be secured from the use of crude petroleum.

They recommend that apparatus for burning oil fuel should be placed on one of the coast defence monitors of the Pacific squadron and in several torpedo boats.

These are some of the more important points covered in this report, which should be seen to be appreciated; it is a most admirable piece of work, and should be in the hands of every one interested in the subject.

A. H. GILL.